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Saving Energy on Montana Farms and Ranches

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INTRODUCTION

Why Energy Management?

Whether you're raising barley on the Fairfield Bench, cattle in the Yellowstone Valley, or cherries near Flathead Lake, you're well aware of the energy costs to fuel the tractor, run the irrigation pump, or perform one of the many other tasks so vital to your operation. But are you aware that some 25 to 35 percent of the energy used each day could be saved? With today's margins between income and costs ranging from slim to none, and the uncertainty of fuel supplies and prices in the future, cutting down on energy use makes sense. In extreme cases of fuel shortages, energy management could make the difference in stretching fuel supplies to finish planting and harvesting.

No Grand Scheme

In the following pages you'll find a collection of tips for reducing energy use on your farm or ranch. No one energy management scheme will work for everyone, but a high percentage of farms and ranches seem to be plagued with common energy pitfalls. Simple practices often take care of these. Many take little or no investment and the savings can be immediate and significant. Some will take more time, money, or a change in management practices, but the return may be worth it.

But Commitment

The most difficult obstacle to energy savings is often a commitment to change. It takes a conscious effort to turn down thermostats, shut off lights, and use tractors more effectively. It takes determination to overcome carelessness and poor planning that cause us to drive 10 miles for a carton of milk or neglect to repair sprinklers. And it takes action. All the good suggestions in the world won't help if you don't try them.

The Next Step

For easy reference, the book is divided into chapters reflecting basic farm operations.

1. **Squeezing Out the Last Drop**
   Equipment and Vehicles
2. **Streamlining the Irrigation System**
   Pumps, Distribution Methods, and Scheduling
3. **Trimming Crop Chemicals**
   Fertilizers and Pesticides
4. **Looking at Livestock**
   Forage Harvesting, Feed Handling, Watering, and Housing
5. **Around the Farmstead**
   Buildings, Lighting, Electric Motors

The appendix lists sources of publications and associations and acknowledges individuals who contributed to the book.

Browse through the book. Do a few things at a time, or only one at a time. You'll be surprised at the dent you can make in that 25 to 35 percent energy waste.

Sprinkled throughout the pages, you'll find successes and suggestions from Montana farmers and ranchers, and we'd like to know yours. What innovations or new practices have worked for you? How did they reduce your energy costs? Drop us a card.

Who's Who in Montana Agriculture

Many of the tips in this book can help any farm or ranch. Some, however, are directed specifically to those operations that comprise a large

part of Montana's agricultural community. Let's look at the makeup of Montana agriculture.

In 1985, 23,600 farm and ranches in Montana covered almost 61 million acres. Crops grew on about 16 percent of the acreage with livestock on the rest. Cattle receipts contributed the most, with wheat close behind as shown in figure 1.

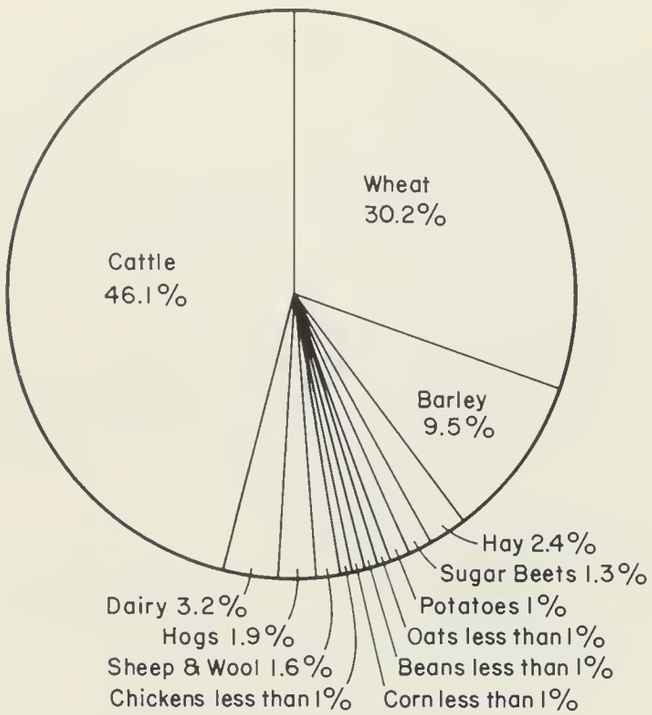


Figure 1. Montana's Major Sources of 1985 Agricultural Income. (Source: Montana Agricultural Statistics Service)

Where Does It Go

Costs to produce these crops and livestock vary significantly from farm to farm depending on land, labor, crop, climate, location, cultural practices, and management. In general, land ownership is the greatest expense (30-50 percent), fertilizer second (15-20 percent), machinery ownership third (10-15 percent), labor fourth (5-15 percent) and energy fifth (4-8 percent).

The preceding figures for energy expenses are somewhat deceiving. They overlook the amount of energy used to manufacture fertilizer. While you can't influence the amount of energy used in the manufacture of fertilizer and pesticides, you can reduce your annual crop chemical use and save energy indirectly. According to a 1982 survey, Montana producers spent about $79,823,000 on commercial fertilizer, and another $43,347,000 on other crop chemicals.

During 1982 Montana farmers and ranchers spent $157,696,000 on energy to operate vehicles, equipment, homes, and irrigation equipment. Over 40 percent of the energy used was in the form of gasoline; 35 percent was diesel, with the rest as illustrated in figure 2.

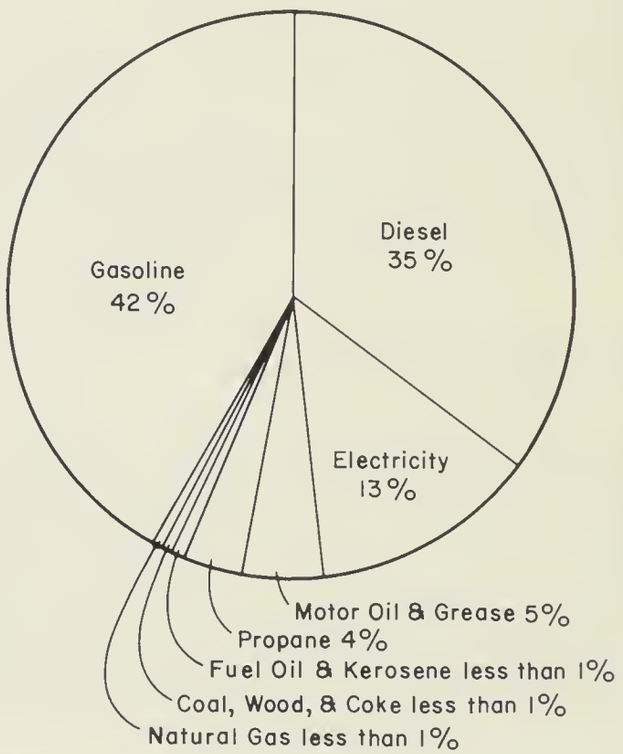


Figure 2. Montana's 1982 Agricultural Energy Expenditures. (Source: Montana Statistical Abstract 1984: A Supplement to Economic Conditions in Montana, 1984, Montana Department of Commerce)

CHAPTER 1

Squeezing Out the Last Drop

Cutting down on fuel use often takes nothing more than changing some ingrained habits, and keeping a closer watch on how and where equipment is operated. You may find that one truck or tractor uses less fuel than another to do the same job. Or that one field operation is particularly expensive in using fuel. In the next few pages you'll find energy-saving tips in these areas:

- Fuel storage
- Vehicle maintenance and operation
- Field practices
- Alternate methods

Look At Fuel Storage

Approximately 120 gallons of gasoline a year (and a lesser amount of diesel) can be lost through evaporation or leaks in above-ground storage tanks. You can reduce these losses to about 15 gallons annually by using all of the following tips (illustrated in figure 3).

- Provide adequate shade for fuel tanks, and paint tanks white or aluminum to reflect the heat from the sun.

- Use pressure relief vacuum caps instead of conventional gasoline fuel caps.

- Inspect for leaks. Tighten fuel connections between the storage tank outlet and the pump, check valve packings, check for seepage at the discharge nozzle.

- Lock unattended fuel tanks.

Note: Underground storage tanks have the least evaporation, but undetected leaks can contaminate groundwater.

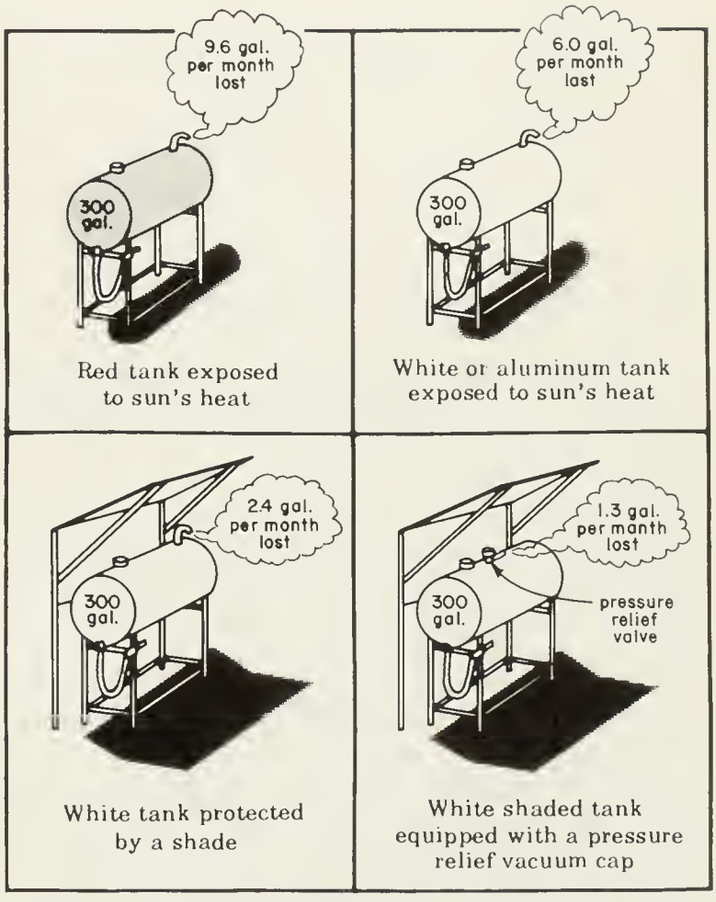

9.6 gal. per month lost
300 gal.
Red tank exposed to sun's heat
6.0 gal. per month last
300 gal.
White or aluminum tank exposed to sun's heat
2.4 gal. per month lost
300 gal.
White tank protected by a shade
1.3 gal. per month lost
300 gal.
pressure relief valve
White shaded tank equipped with a pressure relief vacuum cap

Figure 3. Fuel Evaporation Losses. (Reprinted from Fuels for Agriculture, Wyoming Energy Conservation Office)

Dirt or water in fuel can cause severe loss of fuel efficiency in tractors, especially diesel. Some preventive measures are:

- Using a filter to strip water, dirt and rust from fuel, and trap it in a transparent bowl where it can be drained off.

- Keeping the storage tank full, especially in winter to prevent water condensation.

SAFETY CONSIDERATIONS

- Label gasoline and diesel storage tanks to prevent mistakenly filling a diesel tractor with gasoline which can ruin the diesel injection pump and nozzles.
- Locate storage tanks at least 50 feet from any building, preferably downwind or downhill from the buildings.
- Keep a dry chemical fire extinguisher handy in case of fire.
- Don't smoke around fuel tanks.

Before You Start an Engine

Keep the fuel tank full to avoid condensation, especially in cold weather. When you fill it, leave room for expansion.

Buying a better grade of diesel fuel than you need can be a waste of money. Most owners manuals specify a No. 2-D fuel for warm weather operation and No. 1-D for extreme cold weather work.

For cold weather starts, consider purchasing a small timer and headbolt (electric) heater for warming engines. If you control the length of time the heater runs, it's cheaper to use electricity than liquid fuels to warm engines. Usually 3 hours is sufficient to heat an engine.

If a tractor engine is kept heated all winter for use as a standby generator, you can decrease electrical consumption by installing an air sensing thermostat. Set it at 20 degrees F.

Getting the Most Out of an Engine

A properly working thermostat saves energy. Most engines run most efficiently when water temperature is between 165 and 180 degrees F. Fuel consumption increases by approximately 25 percent when the engine is operating at 100 degrees F instead of 180 degrees F. Check your operator's manual.

Idling can consume 15 to 20 percent of the fuel used. Letting an engine idle for 10 minutes during an average day or 61 hours a year, will use about 30 gallons of fuel on a 75-horsepower diesel tractor.

Quick starts waste fuel and are hard on equipment.

Estimating Fuel Use. By using a "consumption factor" developed by the University of Nebraska and plugging in your figures, you can use the formula in table 1 to estimate your annual tractor fuel use.

Table 1. Estimating Annual Fuel Use

Formula:

Annual Consumption =
Hours Use x Rated Horsepower x Consumption Factor

Consumption factors: diesel- 0.044 gal/hp hr
gasoline - 0.067 gal/hp hr

EXAMPLE:

Approximate annual hours of use = 700
Tractor's maximum rated horsepower = 66

1) Annual diesel consumption =
700 x 66 x .044 = 2,032 gallons

2) Annual gasoline consumption =
700 x 66 x .067 = 3,095 gallons

Note: Adapted from Selecting Power Equipment to Save Energy, Florida Cooperative Extension Service.

Keeping Records. If you're concerned about a vehicle's fuel efficiency, you might want to track the number of gallons you use per acre, or per hour, for each stage in crop production.

Make Time for Tune-ups

Regular tune-ups and maintenance save money--in machinery life, down time, and fuel. We all know this, yet often ignore it. For instance, at Utah State University, tune-ups performed on 176 tractors (171 were diesel) gained an average 21.56 horsepower per tractor. The result was that in average yearly use (450 hours), over 300 gallons of diesel were saved per tractor due to the tune-up. Total parts and labor amounted to $160. With fuel costs of $1.00 per gallon, this meant a net savings of $140.

MAINTAINING FUEL RECORDS BY VEHICLE AND BY TASK

Install a fuel meter on the supply tank to measure the number of gallons in each fill-up.

1. At the beginning of each job, start with a full fuel tank.
2. After the job is finished (and the tractor engine is cool), refill the fuel tank.
3. Calculate fuel use.

   Fuel Use Per Acre--Divide the amount of fuel added by the area worked to get gallons used per acre.

   Fuel Use Per Hour--Jot down the times when you begin and end the field tasks. Subtract the first reading from the second to determine the hours worked. Divide this by the number of gallons needed to fill the tractor.

The sample fuel record in figure 4 shows that disking wheat required 1/2 gallon per acre (15 gallons divided by 30 acres), and 3 gallons per hour (15 gallons divided by 5 hours).

TRACTOR/MODEL # _____

Date	Start Time	End Time	Gallons	Depth	Acres	Crop Operation
9/5	0600	1100	15	7"	30	wheat-disking

Figure 4. Equipment Fuel Record.

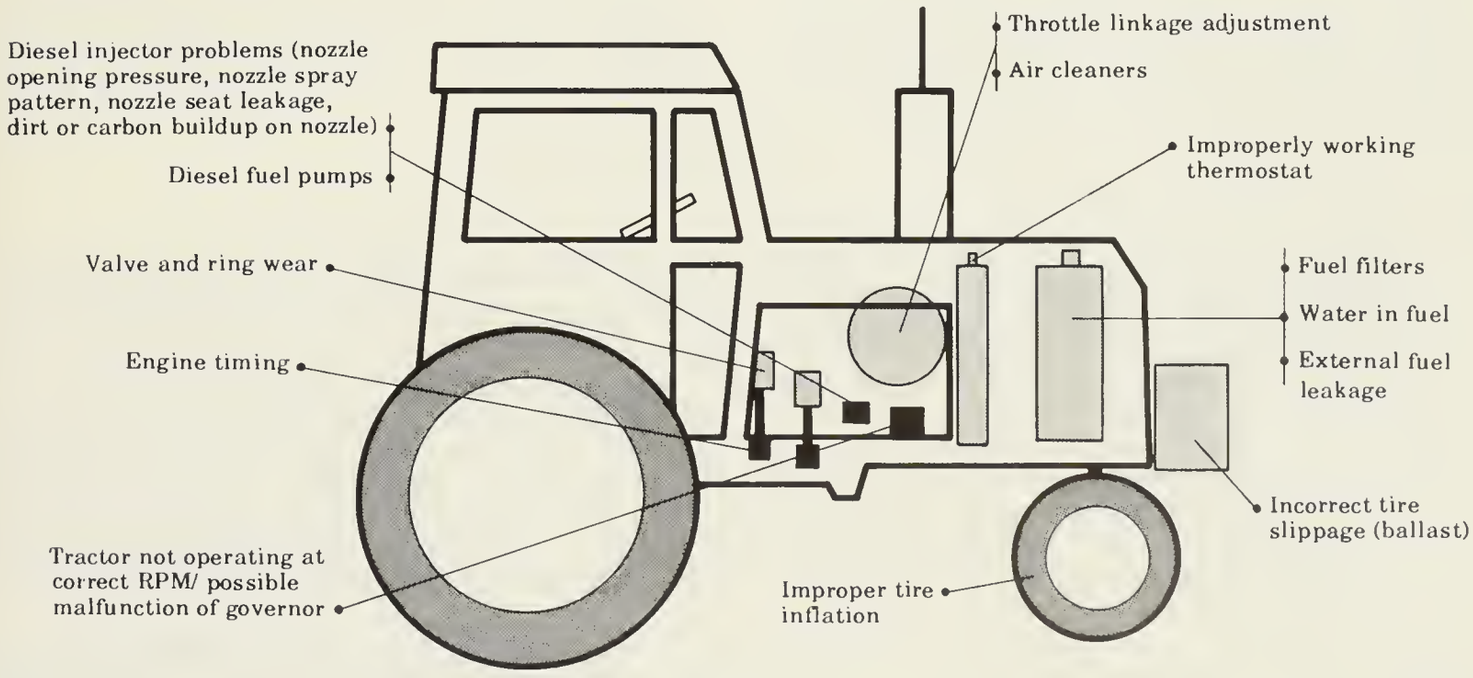

Throttle linkage adjustment
Air cleaners
Diesel injector problems (nozzle opening pressure, nozzle spray pattern, nozzle seat leakage, dirt or carbon buildup on nozzle)
Improperly working thermostat
Diesel fuel pumps
Valve and ring wear
Fuel filters
Water in fuel
External fuel leakage
Engine timing
Incorrect tire slippage (ballast)
Tractor not operating at correct RPM/ possible malfunction of governor
Improper tire inflation

Figure 5. Factors Reducing Fuel Efficiency in a Diesel Tractor. (Adapted from Fuels for Agriculture, Wyoming Energy Conservation Office)

Some things to think about:

- One fouled spark plug or one stuck valve lifter can increase fuel use 10 to 15 percent.
- Blocked air filters can increase fuel consumption up to 25 percent.
- A slowly dripping carburetor can waste up to 1.5 gallons of gas per day.
- Carburetor adjustment affects fuel use. Too rich a mixture wastes fuel; too lean a mixture wastes fuel because it prompts excessive choke use.
- Dry bearings and low oil levels increase fuel consumption from excess friction.
- A loose fan belt causes energy loss due to slippage.
- Underinflated tires can increase fuel use by 5 to 10 percent.

Planning Your Farm Trips

Because farms, ranches, and towns in Montana are often widely separated, fuel costs are higher here than in many other states. In fact, transportation is the third largest energy user in Montana agriculture (after farm chemicals and field operations). Planning ahead often cuts fuel use the most.

- Keep a supply of normal operation and maintenance items on hand to avoid unnecessary trips. Before making a trip, call ahead to make sure the items are in stock. When going to town, accomplish as many jobs as you can and use the most fuel-economical vehicle when possible.
- Carry loads to vehicle capacity to eliminate extra trips but avoid overloading. A 10 percent overload can increase fuel use by about 20 percent. Consider towing a trailer when hauling bulky items to reduce the number of trips.
- Check tire pressure frequently.
- If you have a standard shift, get into high gear as soon as possible. In second gear, you can use 25 percent more gas than in high gear at the same road speed.
- Accelerate slowly, drive at moderate speeds, anticipate stops, and don't ride your brake.
- Use 4-wheel drive only when needed.
- Use small motor bikes for short trips around the farm or ranch.
- Eliminate trips back and forth from shop to field by taking tools and a supply of spare parts to the field.

Saving Fuel in the Field

Fuel consumption rates for field tasks vary widely. Table 2 shows the "average" quantities of gasoline and diesel fuel required for field operations.

TRACTOR OPERATION

The manner in which a tractor is operated can affect fuel consumption by as much as 30 percent. Paying attention to tire slippage, drawbar load, engine speed (rpm), shifting, hitching, and amount of turning and idling can save significant amounts of money.

Tire Slippage

Tractor tire slippage should be from 10 to 15 percent. Ballasting a tractor (adding weight to the rear for increased traction and/or to the front for stability and good steering) can correct slippage. The correct weight to match the job is important. Too much weight increases rolling resistance and strains the tires and drive train; too little weight increases fuel consumption and tire wear. Several pamphlets from the Cooperative Extension Service have a wealth of information about tires. See the appendix of this book for ordering information.

Check advantages and disadvantages of single tires versus duals. In soft, loose soils duals will increase the contact area between the tire and soil, which can be more effective for increasing drawbar power than adding ballast.

Table 2. Energy Requirements for Field Operations (Gallons Per Acre)

Field Operation	Fuel Type Gasoline	Diesel
TILLAGE		
Moldboard plow	2.70	1.90
Chisel plow	1.70	1.20
Offset disk	1.35	0.95
Powered rotary tiller	2.30	1.60
Tandem disk, plowed field	0.95	0.65
Tandem disk, tilled field	0.80	0.55
Tandem disk, cornstalks	0.65	0.45
Field cultivate, plowed field	1.15	0.80
Field cultivate, tilled field	1.05	0.75
Spring-tooth harrow, plowed field	0.70	0.50
Spring-tooth harrow, tilled field	0.65	0.45
Peg-tooth harrow, tilled field	0.25	0.15
PLANTING (30-inch rows)		
Planter only, tilled seedbed	0.45	0.30
Planter with fertilizer and pesticide attachment, tilled seedbed	0.70	0.50
Till-planter (sweep)	0.60	0.40
No-till planter (fluted coulter)	0.50	0.35
Harrow-plant combination	1.15	0.80
Rotary strip-till-plant	1.50	1.05
Grain drill	0.50	0.35
FERTILIZATION		
Applying NH_3, no-till ground	1.47	1.05
Applying NH_3, plowed ground	0.98	0.70
Spraying fertilizer, trail type	0.28	0.20
Spreading fertilizer, dry bulk	0.28	0.20
WEED CONTROL (30-inch rows)		
Sprayer, trailer type	0.10	0.07
Rotary hoe	0.25	0.15
Sweep cultivator	0.65	0.45
Rolling cultivator	0.60	0.40
Sweep cultivator, with disk tillers	0.70	0.50
Powered rotary cultivator	1.00	0.70

Field Operation	Fuel Type Gasoline	Diesel
HARVESTING		
Cutterbar mower	0.55	0.35
Hay conditioner, trailed	0.55	0.35
Mower conditioner, PTO	0.85	0.60
SP windrower	0.90	0.60
Rake	0.35	0.25
Baler	0.65	0.45
Stack-forming wagon	0.70	0.50
Forage harvester		
Green forage	1.35	0.95
Haylage	1.80	1.25
Corn silage	5.20	3.60
High-moisture ground ear corn	2.75	1.90
Forage blower		
Green forage	0.50	0.35
Haylage	0.35	0.25
Corn silage	2.00	1.40
High-moisture ground ear corn	0.65	0.45
Combine		
Small grain	1.50	1.05
Corn, 30-inch rows	2.35	1.65
Sugar beet harvester	2.10	1.45
Fruit tree shaker	4.00	2.80
HAULING, Field + 1/2 Mile on Graveled Road		
Green forage	0.55	0.35
Haylage	0.30	0.20
Corn silage	2.00	1.40
Corn grain	0.30	0.20
HAULING, Add following values to those above for each additional mile on gravel road		
Green forage	0.20	0.14
Haylage	0.30	0.20
Corn silage	1.30	0.90
Corn grain	0.20	0.15

Note: The estimates include only the fuel required for actual field work; no allowance is made for machine preparation, travel to and from the field, or travel between fields. Because fuel consumption for each specific operation varies among tractors, operators, soil types, yields, and other factors, actual fuel usage can fluctuate as much as 50 percent from the values listed in table 2. The value of the table is to compare fuel usage for different tasks.

Fuel use is calculated for loam soils. For lighter draft (sandy) soils, decrease fuel values by about 35 to 40 percent for primary tillage, 20 percent for planting, and 10 to 15 percent for secondary tillage and cultivation. For heavier draft soils (clays), increase fuel values by the same percentages. Values are based on 7-inch plowing depth and 4- to 5-inch operating depth for other tillage machines. Field speeds are assumed to be 4 to 5 mph for all tillage operations, 5 mph for planting and spraying, 4 to 5 mph for forage harvesting and 2 1/2 to 3 mph for grain harvesting.

All values assume efficient materials handling in the field, proper tractor weighting to keep wheel slippage below 15 percent, properly tuned and adjusted tractor engines, and efficient part-load tractor operation.

Source: Adapted from Fuels for Agriculture, Wyoming Energy Conservation Office, Estimating Fuel Requirements for Field Operations, Cooperative Extension Service, Purdue University, and The Dairy Farm Energy Book, Cooperative Extension Service, University of Vermont.

CHECKING TRACTOR TIRE SLIPPAGE: TREAD MARKS

An approximate method for checking proper ballast is to observe the tire tread pattern (figure 6) produced when pulling under load, using the following guidelines:

Too little weight--the tread marks are wiped out entirely due to excessive slippage, which reduces forward progress.

Too much weight--the tire tracks will be sharp and distinct in the soil.

Proper weight--the soil between the cleats in the tire pattern is shifted, but the tread pattern is still visible.

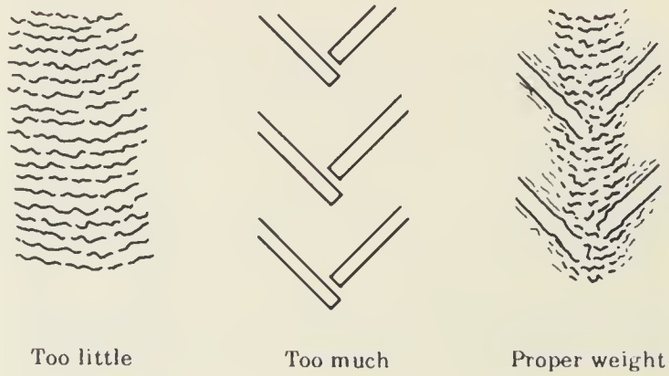


Figure 6. Tire Traction Patterns. (Reprinted from Tractor Ballasting to Conserve Fuel, Florida Cooperative Extension Service)

CHECKING TRACTOR TIRE SLIPPAGE: MEASURING

A more accurate way to determine slippage is to compare the number of rear wheel revolutions when the tractor is not under load with the number of revolutions under full load. When the tractor is under full load, the drive wheels should make about 10 revolutions compared with 8 1/2 when it's not under full load to advance the same distance (figure 7).

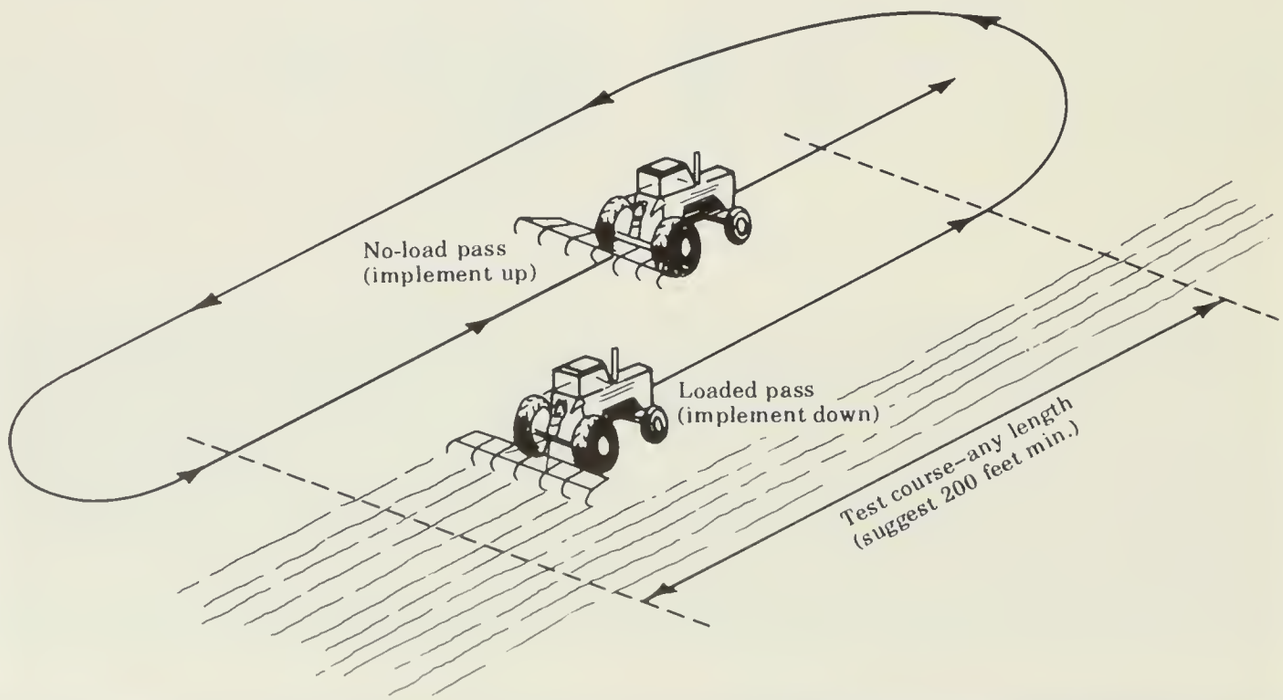


Figure 7. Calculating Tire Slippage. (Adapted from Tractor Weighting and Tire Selection, Northeast Regional Agricultural Engineering Service) and Conservation, Storage & Handling of Fuel for Farm Machinery, Cooperative Extension Service, Purdue University)

You can easily determine the percent of tire slippage by following 6 steps. You'll need one other person as well as paint, tape, or chalk, and 2 marker stakes.

1. With paint, tape, or chalk, make a reference mark on the sidewall of the rear tire.

2. While the tractor is performing a heavy draft operation at field speed, place the first stake to mark the spot where the tire meets the soil.

3. Walk beside the tractor counting 10 revolutions of the wheel.

4. Use the second stake to mark the spot where the tire mark again meets the ground on the tenth revolution.

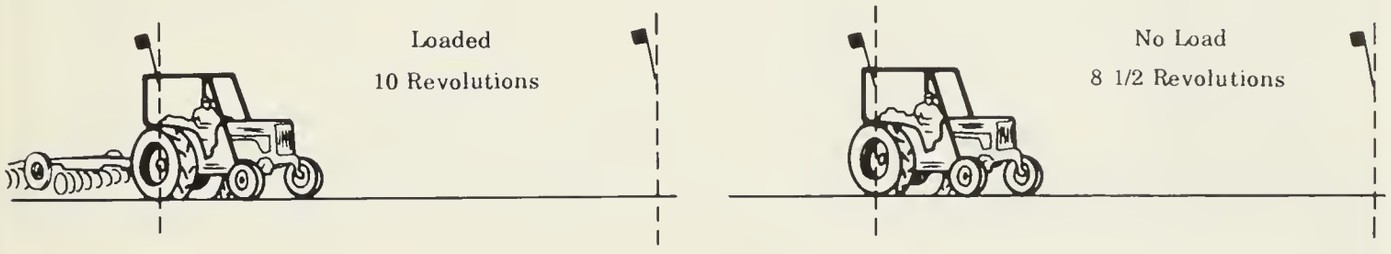
5. Take the implement out of the ground and again operate the tractor between the two stakes. Count the number of rear wheel revolutions for the tractor to cover the staked distance while pulling no load. Estimate the last wheel revolution as closely as possible.

6. Calculate the slip by this formula:

$$\% \text{ Slip} = \frac{(10 - \text{the no load revolutions}) \times 100}{10}$$

EXAMPLE: If 8.5 revolutions occurred for the staked distance with no load, the percent of slip would be:

$$\% \text{ Slip} = \frac{(10 - 8.5) \times 100}{10} = 15\%$$



Use table 3 as a guide for the addition or removal of ballast.

Table 3. Criteria for Addition or Removal of Ballast

% Slip	Result
0 to 5	Remove weight
10 to 15	Proper weight
20 to 25 (or more)	Add weight

Source: Fuels for Agriculture, Wyoming Energy Conservation Office.

Remember that a towed implement requires more ballast than a mounted implement. The mounted implement provides weight transfer to the rear tires that acts as additional ballast which helps to control slippage.

Drawbar Work

Gear up, throttle down. Studies show that on the average the drawbar load on a farm tractor is only 50 percent of its rated capacity. For partial drawbar loads gearing up and throttling down to reduce engine speed (rpm) can save up to one-third in fuel as illustrated in table 4. (The typical average fuel saving is about 1 percent for each 1 1/2 percent that engine speed is reduced below maximum rated rpm.)

Fuel efficiency increases per horsepower output up to about 80 percent of the maximum horsepower possible at that engine speed, as illustrated in figure 8.

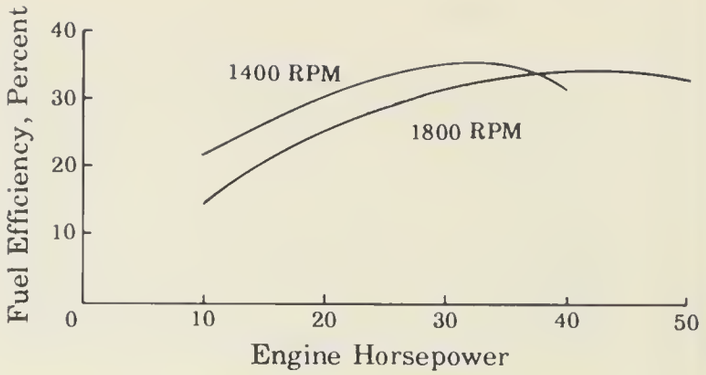


Figure 8. Effect of Engine RPM and HP Output on Fuel Efficiency. For the tractor tested, the best fuel efficiency was obtained at about 30 horsepower and 1400 rpm. (Adapted from Tractor Operation for Fuel Savings, Florida Cooperative Extension Service)

Table 4. Potential Fuel Savings with the Shift-Up and Throttle-Back Method

Tractor Type Maximum DBHP*	Fuel Consumption, 50% of Pull at Maximum Power** In Rated Gear, Full-Throttle	In Higher Gear, Part-Throttle	Net Fuel Savings
	Gal/Hr	Gal/Hr	Percent
4WD - 262 Hp	13.8	9.8	29.0
4WD - 228 Hp	13.0	8.8	32.3
4WD - 189 Hp	9.9	8.1	18.2
4WD - 156 Hp	7.9	6.1	22.8
2WD - 149 Hp	8.6	6.5	24.4
2WD - 128 Hp	6.7	5.4	19.4
2WD - 121 Hp	6.4	5.5	14.1
2WD - 102 Hp	5.4	4.2	22.2
2WD - 92 Hp	4.9	4.0	18.4

*Tractors were selected to represent the range in sizes and types available for heavy field work. DBHP means drawbar horsepower.

**Both tests conducted at the same drawbar pull and speed resulting in the same drawbar horsepower.

Note: Reprinted from Conservation, Storage & Handling of Fuel for Farm Machinery, Bulletin AE-116, Cooperative Extension Service, Purdue University.

Because of the dropoff in fuel efficiency at higher loads, many diesel engines run more efficiently at 50 percent load and a reduced engine speed than at 100 percent load and full engine speed. Therefore, a large diesel tractor used for light drawbar loads can actually use less fuel **if geared up and throttled back** than a smaller tractor working at its full rated capacity.

For best fuel efficiency, select the gear that provides the desired ground speed at the reduced engine rpm, without overloading. (Overloading is indicated by black smoke or sluggish response to acceleration. Check your owner's manual for the "working rpm range" of your tractor.)

Hitching. Power and fuel are wasted if your tractor and implements "fight" each other as they move through the field. Align soil engaging parts of tillage tools for minimum draft as illustrated in figure 9.

Equipment speed. Check your operator's manual for the proper equipment speed. Doubling ground speed can triple power requirements, resulting in more fuel use.

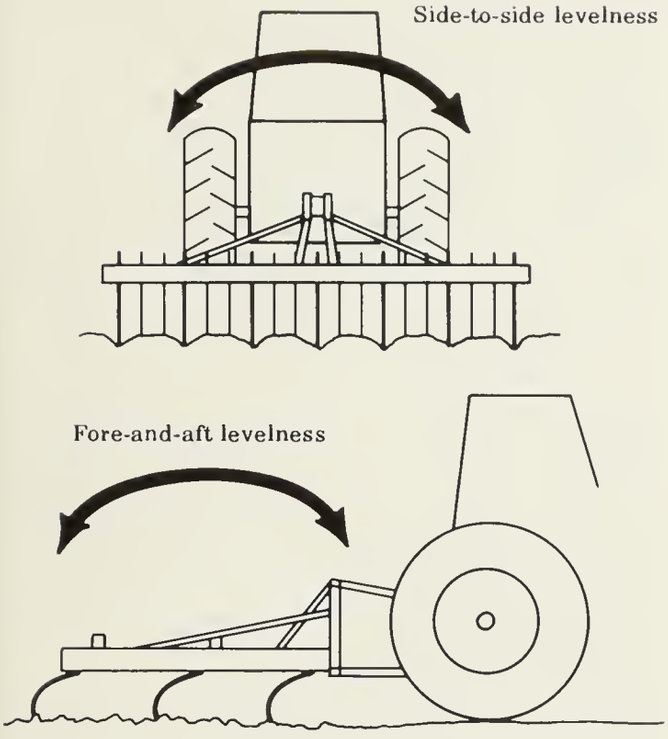


Figure 9. Implement Hitching and Levelness. (Reprinted from Conservation, Storage & Handling of Fuel for Farm Machinery, Cooperative Extension Service, Purdue University)

Combine tasks. Pull more than one implement at a time behind a tractor--combine an herbicide sprayer with a harrow, pull a planter behind a disk, use a disk-seeder combination.

Tilling. Plowing deeper than necessary causes more soil to be moved and increases fuel consumption. Fields too wet or too dry increase fuel use. Dull plowshares and improper clearance can increase fuel consumption up to 30 percent.

Power-Take-Off (PTO) Work

For maximum fuel efficiency in PTO work, it is especially important to match tractors to the load. A tractor engine operating at proper rpm for the PTO-driven machinery, but loaded to only 45 percent of its rated horsepower will deliver about 80 percent as much work per gallon of diesel and about 70 percent per gallon of gasoline. Figure 10 compares the fuel used for the same PTO job by half and fully loaded gasoline and diesel tractors.

Because PTO-driven machinery has to be driven at its rated rpm in order to work properly, the tractor operator can't throttle back to a lower rpm to improve fuel efficiency as he can in drawbar work.

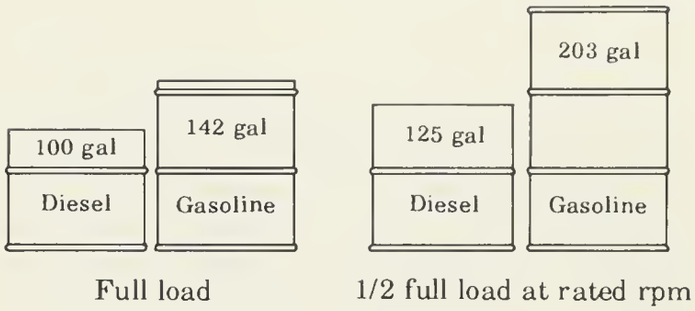


Figure 10. Fuel Use Comparison for PTO Jobs. (Reprinted from Selecting Power Equipment to Save Energy, Florida Cooperative Extension Service)

Matching Equipment to Task

Ask yourself if certain practices can be slowly siphoning your energy dollars. Take a look around and see where better planning or a small investment might save energy and money in the long run. Some questions might be:

- How many trips are you making to repair flats caused by using old automobile tires on wagons that are constantly loaded beyond tire capacity?
- How often do broken axles require trips to town because you're using 3-ton wagon gear under forage boxes that require up to a 10-ton running gear?
- Would a larger seed hopper decrease trips to refill planters?
- Is your disk so small that it takes an extra pass between rows; or is it so excessively wide that it requires too much horsepower?

Travel Patterns

Lay out your fields to minimize turns and to keep the tractor on a level path (keeping erosion control practices in mind). Coordinate livestock

grazing location with tractor field work to minimize idling time when opening and closing gates. Installing cattle guards can eliminate stopping and idling time.

REDUCED TILLAGE

Depending on your location, crop, and management style, you may be able to adopt minimum tillage as a method for reducing energy requirements. The trade-off is the possible increase in the amount of extra chemical used for weed control and fertilizer. The Cooperative Extension Service at Montana State University in Bozeman has information on alternate tillage studies recently done in Montana.

In conventional tillage, the operator will normally plow, disk, and harrow before and after planting. Reduced tillage minimizes these operations by either eliminating seedbed preparation or combining it with other field operations like planting. Conserving on field work during the critical pre-plant and post-harvest periods can help smooth out manpower needs during Montana's short growing season.

Reduced tillage also extends the life of equipment and delays replacement purchases, resulting in less energy being expended for manufacturing equipment and maintaining it.

In 1985 Montana farmers and ranchers used reduced- or no-tillage practices on more than one-third of the state's 8.5 million acres of crop land.

Some practices to consider that will minimize secondary tillage are:

- Prepare the seedbed just ahead of planting to reduce the chances of rain between preparation and planting, and the possibility of having to reseed. Prepare a seedbed only in the row area, leaving the middle rough.
- Combine operations: the final seedbed preparation with planting, the fertilizer operation with a tillage operation, and so forth.
- Use herbicides that don't require incorporation where weed problems are minimal. Or plant at optimum time to combat weeds by crop competition, reducing the need for herbicides.

Over the last 3 years Chip Fosland has averaged 200 to 250 hours per year on his tractor compared to the 800 hours before he began his no-till, reduced-till operation on his Daniels County farm. Instead of buying oil by the 30-gallon barrel and filters by the case, he now buys oil in 5-gallon jugs and filters one at a time. His tires last longer and his maintenance costs are considerably less. Fosland figures his tractor will last four times longer.

Plus, he says, his plants seem to be healthier since no-till. They get more water because he captures more snow, and the soil isn't drying out from spring tillage operations which allows a shallower seeding depth. Although he increased his chemical use somewhat, he still comes out on the positive side with the great reduction in fuel and machinery costs. In one area where he's been no-tilling and continuous cropping, even his chemical costs have decreased.

OTHER FUEL-CUTTING IDEAS

Chisel plowing followed by one disking will use less fuel than moldboard plowing. Using a chisel plow will also let you cover more acreage in a day.

Field cultivators will prepare a good seedbed with less draft (and lower energy requirements) than comparable width disk harrows.

In dryland areas forage grasses such as blue grama, crested wheatgrass, or switchgrass produce more feed per unit of water used.

Soil maps can help match soil to crop. See your local Soil Conservation Service.

Where practical, restricting machinery transport across fields to "permanent" tracks reduces tillage draft and results in fuel savings.

Using the lightest-weight, practical ATV (all-terrain vehicle) for spraying, spreading, rock picking, or transportation chores can save fuel. The ATV also can move in fields too wet for heavier equipment. Tow it behind implements to use for short trips between fields.

Orchards

In Western Montana orchards, regular maintenance on orchard heaters will save fuel.

- Clean heaters and check bottoms and joints to be sure they are tight with no leaks.
- Regulate hot-stack type of heaters 1 minute after lighting for good draft.
- Check heater regularly during the night and adjust to control burning rates and conserve fuel.

Depending on fuel costs, alternative frost protection methods may pay in the long run. If you have plentiful water, overtree sprinkling may be practical. If not, overtree fans might be feasible.

When It's Time To Replace

When considering the type of machinery needed for particular jobs, compare the fuel requirements of different makes and models. Reduced fuel costs can more than compensate for higher purchase price.

You might want to write for the Nebraska Tractor tests (the appendix has the address). These tests compare the fuel efficiencies of different tractors. You'll find data for both PTO horsepower and drawbar horsepower.

Other things to keep in mind when purchasing equipment:

- If horsepower and running time are equal, a diesel tractor will use 0.7 as many gallons of fuel as a gasoline tractor. A propane-powered tractor will use 1.2 as many gallons of fuel as a gasoline tractor.
- Tractors with all gear power transmission are 25 percent more fuel efficient than hydraulic drives, even at reduced engine speed, and with part load as well as at full, according to Nebraska tests.
- The radial ply tractor tire is the most efficient in converting horsepower to drawbar pull because of more tire-soil contact.
- Purchasing equipment that can perform several jobs at once eliminates trips.
- Cars or pickups with electronic ignition and radial tires get better fuel economy.

An example of fuel usage comparison is shown in table 5. Fuel efficiency in tractors is measured in horsepower hours (work) per gallon--the higher the rating, the more economical the equipment. Notice that both tractors have similar drawbar horsepower at 100 percent load. Since tractors rarely operate at maximum power, the average drawbar load (at 75 percent) is used to compare fuel consumption.

Table 5. Diesel Tractor Fuel Efficiency

	TRACTOR A	TRACTOR B
	Horsepower	
100% drawbar load	130.93	130.33
75% drawbar load	107.76	106.58
50% drawbar load	71.91	72.56
	Fuel Efficiency	
	Horsepower Hours/Gallon	
100% load	12.04	13.30
75% load	10.91	12.15
50% load	9.11	10.32

Source: Nebraska Tractor Test Data.

Note: Tractor A when delivering an average output of 107.76 horsepower gets 10.91 drawbar horsepower hours per gallon. Thus, Tractor A will use 9.88 gallons per hour (107.76 horsepower x 1 hour/10.91 horsepower hours per gallon = 9.88 gallons).

Tractor B uses substantially less diesel fuel. When delivering an average output of 106.58 horsepower, Tractor B gets 12.15 drawbar horsepower hours per gallon. Thus, Tractor B will use 8.77 gallons per hour.

For 600 hours of use, Tractor A would require 5,928 gallons of diesel fuel. On the other hand, Tractor B would use 5,262 gallons of diesel. At $1.00 per gallon for diesel fuel, the selection of Tractor B would save over $650 annually.

CHAPTER 2

Streamlining the Irrigation System

Inefficient pumping plants, leaky or undersized distribution systems, high pressure, and overwatering are costing Montana farmers and stockmen thousands of dollars in water, fuel and fertilizer. Agricultural experts estimate that approximately 10 to 20 percent of irrigation costs might be cut by more intensive management and irrigation system maintenance.

Consider that a center pivot sprinkler system, pumping from a depth of 100 feet against a pressure of 75 psi, takes 50 gallons of diesel fuel or its equivalent in electricity or other fuels to irrigate 1 acre. This is 10 times the energy needed for plowing, disking, planting, cultivating, and harvesting the same acre. A 10 to 20 percent savings in this case would be a major benefit for the budget.

Almost any pumped irrigation system can be improved at the pumping plant or in the distribution system. The irrigator who practices good irrigation management conserves water along with energy. In the next few pages you will find cost-cutting suggestions for:

- Pumping plants
- Sprinkler irrigation
- Surface irrigation
- Scheduling irrigation

The Pumping Plant Bottleneck

An irrigation pumping plant operating at reduced efficiency can take a sizeable toll on your budget. In many irrigation systems, it is doing just that. In Wyoming recently, tests of pumping plants revealed that over half were using much more energy than necessary. While top efficiency of a good electric pump approaches 70 percent, some systems were found operating at only 35 percent efficiency.

Dollar savings from improved pumping plant performance can be substantial. A grower pumping 2 acre-feet of water over 300 acres will pay several thousand dollars more in operating costs for a pump operating at 40 percent efficiency than for one working at 70 percent efficiency. Take a look at estimated costs and savings for an electric pump at various kilowatt hour charges:

Cost per kWh	40 Percent Efficiency	70 Percent Efficiency	Savings
$ 0.03	$ 5,850	$ 3,375	$ 2,475
0.04	7,800	4,425	3,375
0.05	9,750	5,625	4,125

What can you do? Often it's a combination of problems that causes inefficient pumping plant operation. Some of these can be cured through low-cost remedies. Others can take more money or time, but can pay off in big dividends. Here are some suggestions.

INSTALLATION

Pumping plant configuration can influence its energy use substantially. Figure 11 shows recommended pump installation when pumping from a canal, river, or other surface source. The short, direct suction pipe reduces the vertical lift of water to the pump. Turns and obstructions are removed to provide an even flow of water and to decrease total lift. Eccentric (flat on top) cone reducers and smooth, long-radius pipe bends minimize friction. Screens at the sump inlet rather than on suction bells keep trash from interfering with the intake pipe.

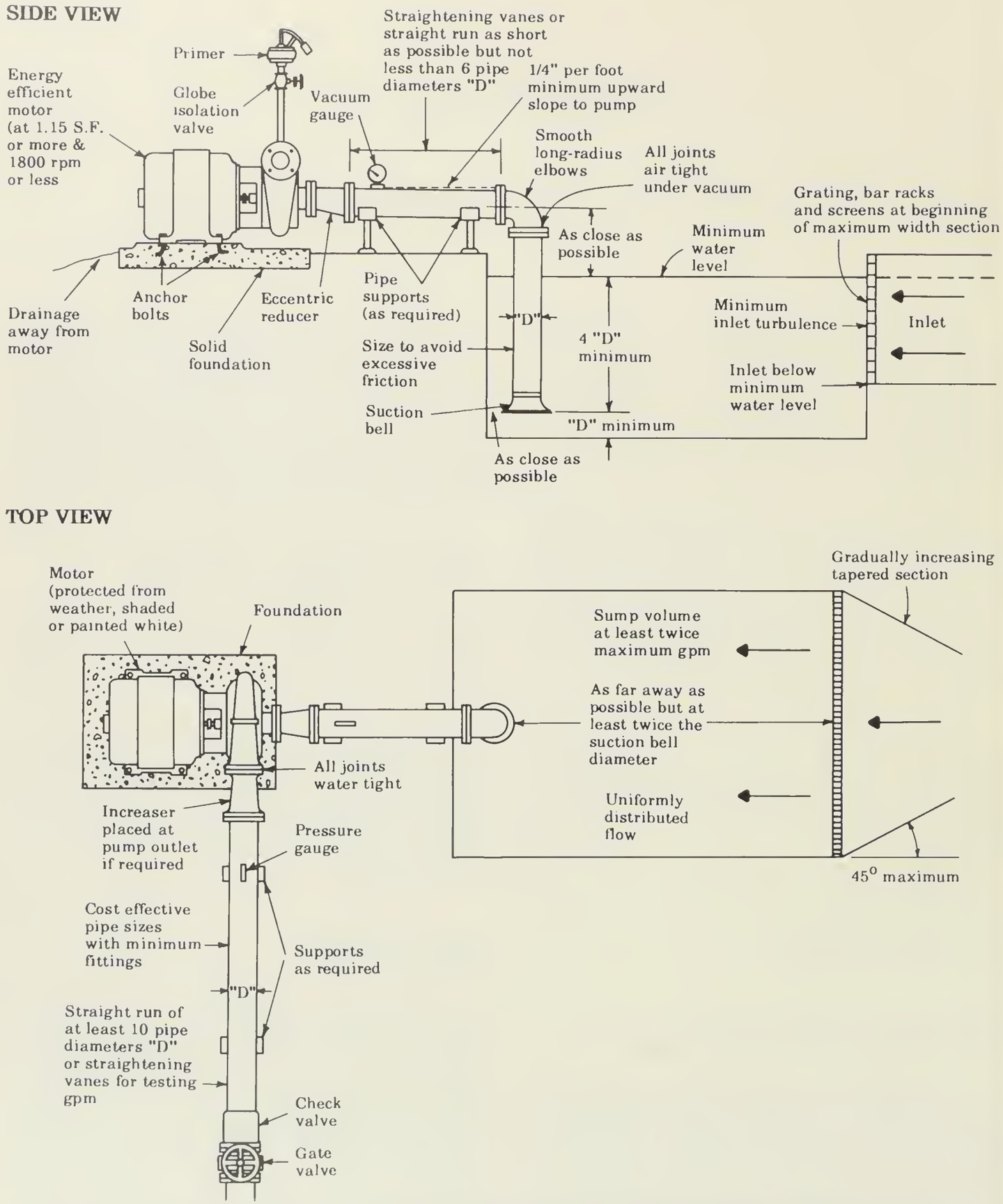

SIDE VIEW
Straightening vanes or straight run as short as possible but not less than 6 pipe diameters "D"
1/4" per foot minimum upward slope to pump
Primer
Energy efficient motor (at 1.15 S.F. or more & 1800 rpm or less
Globe isolation valve
Vacuum gauge
Smooth long-radius elbows
All joints air tight under vacuum
Grating, bar racks and screens at beginning of maximum width section
As close as possible
Minimum water level
Drainage away from motor
Anchor bolts
Eccentric reducer
Pipe supports (as required)
"D"
Minimum inlet turbulence
Inlet
Solid foundation
Size to avoid excessive friction
4 "D" minimum
Inlet below minimum water level
Suction bell
"D" minimum
As close as possible
TOP VIEW
Motor (protected from weather, shaded or painted white)
Foundation
Gradually increasing tapered section
Sump volume at least twice maximum gpm
As far away as possible but at least twice the suction bell diameter
All joints water tight
Uniformly distributed flow
Increaser placed at pump outlet if required
Pressure gauge
45° maximum
Cost effective pipe sizes with minimum fittings
Supports as required
"D"
Straight run of at least 10 pipe diameters "D" or straightening vanes for testing gpm
Check valve
Gate valve

Figure 11. Recommended Pump Installation. (Reprinted from Energy Efficient Pumping Standards, Utah Power & Light Company)

Efficient deep well pumping requires a stable, properly designed and constructed well. If you suspect problems, it may pay to have your well checked. Clogged well screens inhibit water flow into the well. This can cause a lowered water level inside the well casing resulting in increased pumping lift. Casing perforations above the pumping water level of a well cause cascading water, which results in pumping air. Pumping air also occurs when the pump capacity exceeds the well capacity. Figure 12 illustrates the criteria for deep well construction.

If you are discharging into a canal, ditch, or reservoir and have more than a 2-foot drop between the pump and the discharge point, direct the flow outlet below the normal water surface level of the ditch, as shown in figure 13. This provides suction head which recovers some of the energy used in lifting the water from the source to the pump. Equip your discharge pipe with as few elbows and fittings as possible, and use smooth long-radius pipe bends to minimize friction losses.

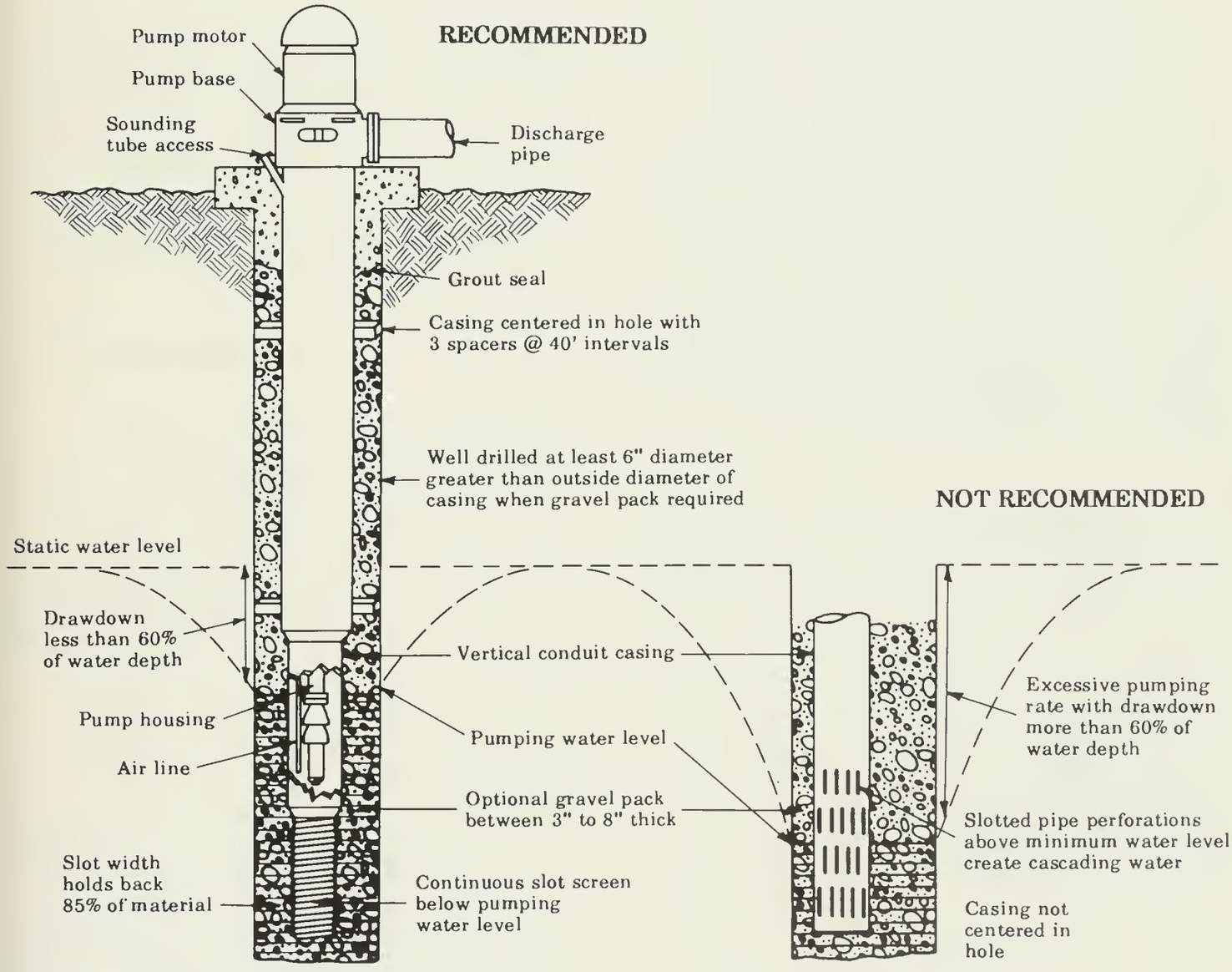

RECOMMENDED
Pump motor
Pump base
Sounding tube access
Discharge pipe
Grout seal
Casing centered in hole with 3 spacers @ 40' intervals
Well drilled at least 6" diameter greater than outside diameter of casing when gravel pack required
NOT RECOMMENDED
Static water level
Drawdown less than 60% of water depth
Vertical conduit casing
Pump housing
Pumping water level
Air line
Optional gravel pack between 3" to 8" thick
Slot width holds back 85% of material
Continuous slot screen below pumping water level
Excessive pumping rate with drawdown more than 60% of water depth
Slotted pipe perforations above minimum water level create cascading water
Casing not centered in hole

Figure 12. Deep Well Construction. (Reprinted from Energy Efficient Pumping Standards, Utah Power & Light Company)

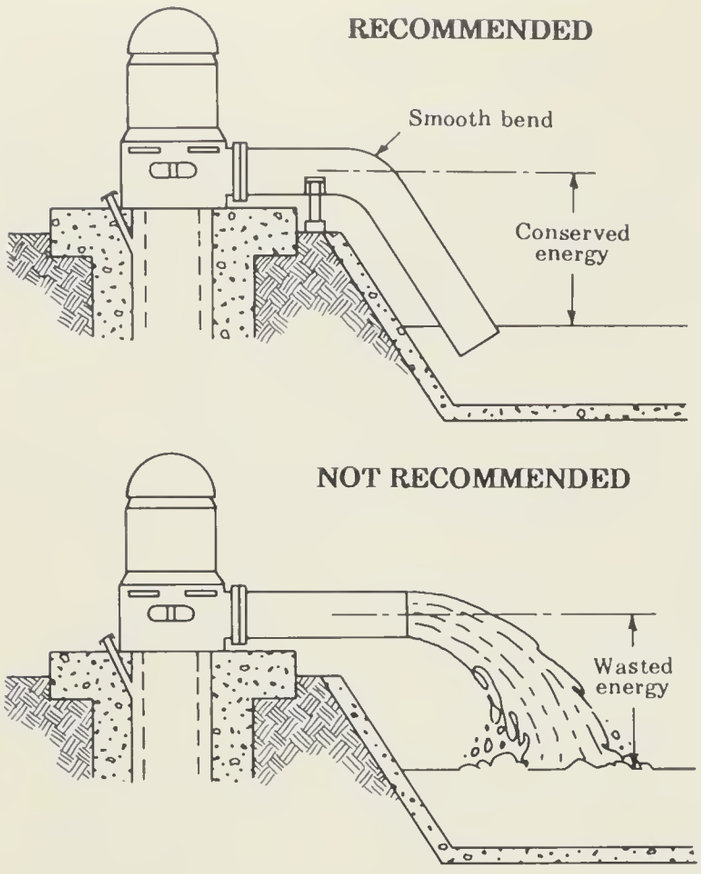


Figure 13. Pump Discharge Point Configuration. (Reprinted from Energy Efficient Pumping Standards, Utah Power & Light Company)

When discharging into a mainline, discharge fittings larger than the size of the pump's discharge minimize friction. Cone increasers minimize head loss and turbulence and prevent the formation of air pockets. Figure 14 illustrates the difference in fittings.

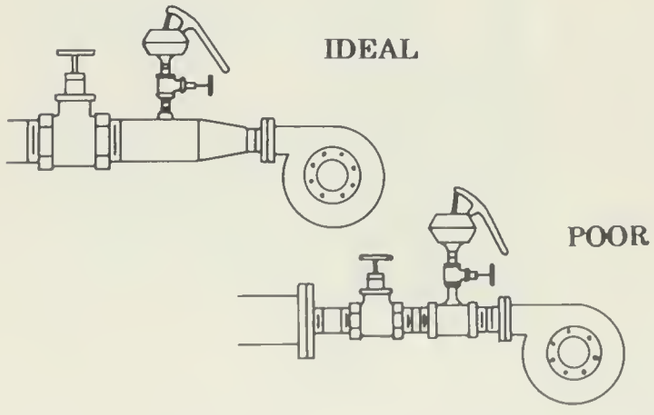
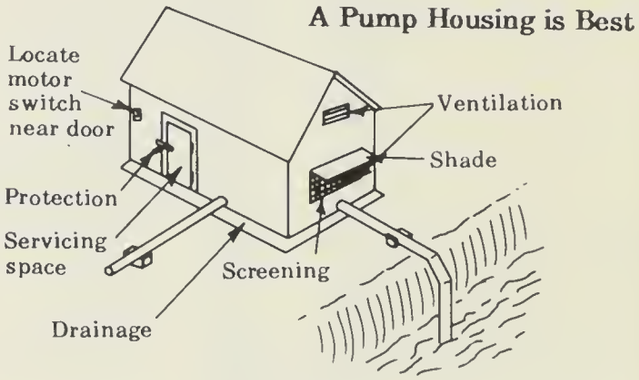


Figure 14. Pump Discharge Fittings. (Reprinted from A Guide to Energy Efficient Pumping, Umatilla Electric Cooperative Association)

A quality, liquid-filled pressure gauge that you can glance at daily is a good investment. Changes in pressure will signal clogged intake screens, leaks, pump wear, or other system trouble.

A totalizing flow meter should be part of an irrigation system. The flow rate indicator is another way to tell if screens are clogged or the pump is malfunctioning. Its greatest value is in managing the amount of water applied during each irrigation. By knowing acres irrigated and acre feet applied, it's easy to figure inches applied.

Direct radiation from the sun can easily increase internal motor temperature by 10 to 20 degrees F and heat is the main cause of reduced motor life. For each 18 degree F temperature rise, motor life is cut in half. You can paint the motor a reflective white or light color to reduce solar radiation heat gain. Or, you can shelter it as shown in figure 15 to provide a cool, dry, clean environment. When sheltering the motor, locate vent openings to direct air flow around the motor and to prevent entry of blowing dirt.



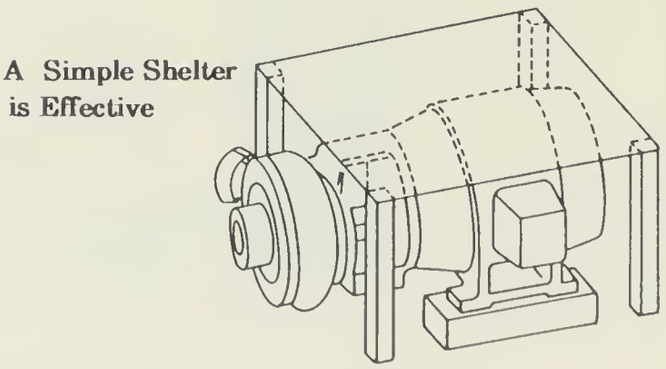


Figure 15. Suggested Pump Housing. (Reprinted from A Guide to Energy Efficient Pumping, Umatilla Electric Cooperative Association)

OPERATION

If your monthly electric charge is based on the maximum 15-minute demand used by the pumping plant during that period, you might be able to save some money through careful initial start-up. Much less power is required to start high or medium head centrifugal pumps with the discharge gate valve closed. Once started, partially open the gate valve until all lines are filled; then open it completely. This will also help prevent waterhammer which is potentially damaging to lines and pressure/flow regulators.

Use variable speed motors, flow control nozzles, or more than one pump when greater head is needed temporarily. Trying to control the discharge rate by using flow control valves is similar to driving your car with one foot on the brake and the other foot on the accelerator.

Automatic timers can switch off pumps during periods when it is inconvenient to turn them off manually to avoid over irrigation.

MAINTENANCE

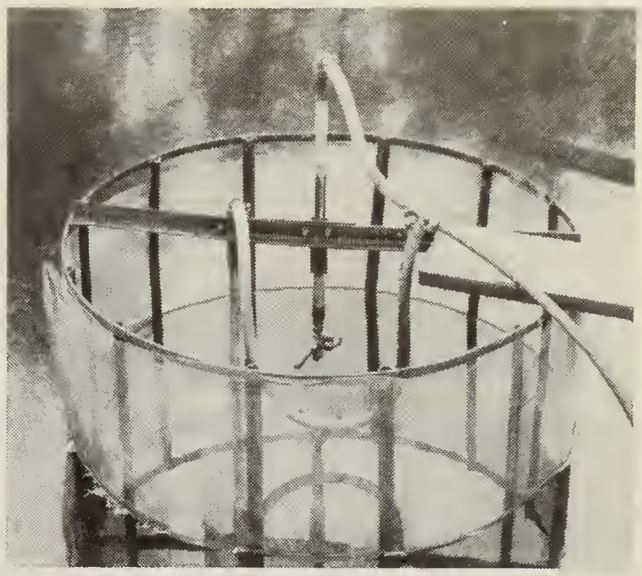
Caked-on dirt and oil, and obstructions over motor vents all cut into good efficiency. Check the "Around the Farmstead" chapter for tips on maintaining electric motors.

Tune-ups on internal combustion engines reduce fuel consumption and increase power. "Squeezing Out the Last Drop" chapter earlier in this book has a checklist for tune-ups.

Carefully following the manufacturer's recommendations for maintenance on pumping plant components is just good sense. Partially-plugged intake screens, air leaks in suction lines, shaft misalignment between pumps and motors, over-tightened packing glands or seals, and leaky fittings all cut into good pump efficiency.

Periodically clean the trash screens. (A self-cleaning, non-powered screening system developed at the Snake River Conservation Research Center in Kimberly, Idaho, might save you labor and time. Their address is in the appendix.)

When you winterize your system, check for potential problems in the motor, pump, and lines.



When irrigating at his Tomahawk Ranch near Whitehall, Doug Salsbury uses sprinklers at each sump to continuously wash off the trash. The force of spray from the sprinkler head removes leaves and other debris sucked against the trash screen. A line extending from the pump's discharge supplies the water to drive the trash cleaning system.

CHECKING PUMPING PLANT PERFORMANCE

A professional pumping plant test can tell you whether energy and money can be saved by adjusting, rebuilding, or replacing the existing pump, drive systems, or power unit. Although increasing pump efficiency can be expensive depending on the problem and cause, the payoff is lifting the same amount of water for 50 to 74 percent of the power bill. (In recent Nebraska tests, over one-third of the pumping plants were using 30 percent to 200 percent more energy than necessary. Pump adjustments requiring less than one-half hour of labor for most pumping plants resulted in savings of up to $1,350 per year.)

Several books listed in the appendix describe causes of pumping plant inefficiency and what pumping plant tests can reveal.

ESTIMATING YOUR PUMP'S EFFICIENCY

This method will help you estimate your pump's efficiency. It doesn't include the efficiency of the rest of the irrigation system, such as mainline losses.

To conduct the test, you'll need:

- A working pressure gauge on the discharge side of the pipe (shown in figure 16).
- A 5-gallon bucket and hose, **or** a flow meter mounted 5 pipe diameters downstream of the pump or other bends or changes in pipe (figure 17).
- A stopwatch, and a calculator.

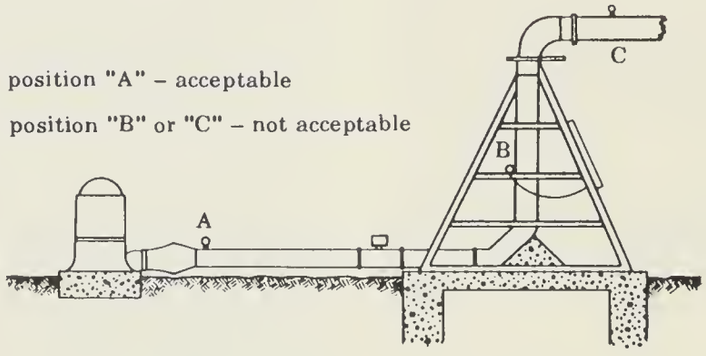


Figure 16. Pressure Gauge Location. (Adapted from Revised Irrigation Pumping Plant Test Procedure Manual 1985, Western Area Power Administration)

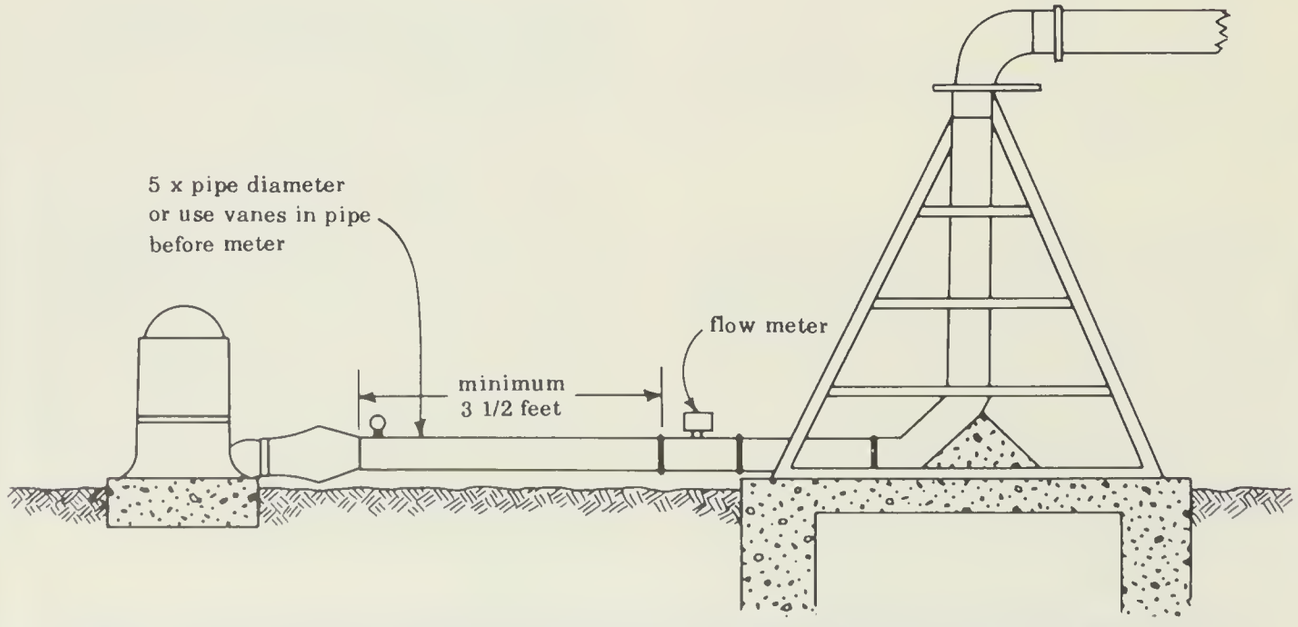


Figure 17. Flow Meter Placement. (Adapted from Revised Irrigation Pumping Plant Test Procedure Manual 1985, Western Area Power Administration)

When the system is operating under normal, steady conditions, enter these calculations:

1) FIND TOTAL DYNAMIC HEAD (TDH)

Read pressure from gauge _____ PSI x 2.31 = _____ FEET

Height* in feet IF pump is ABOVE water surface + _____ FEET

or

Height* in feet IF pump is BELOW water surface - _____ FEET

*Height is the distance from the water surface to center line of the discharge pipe as illustrated in figure 18.

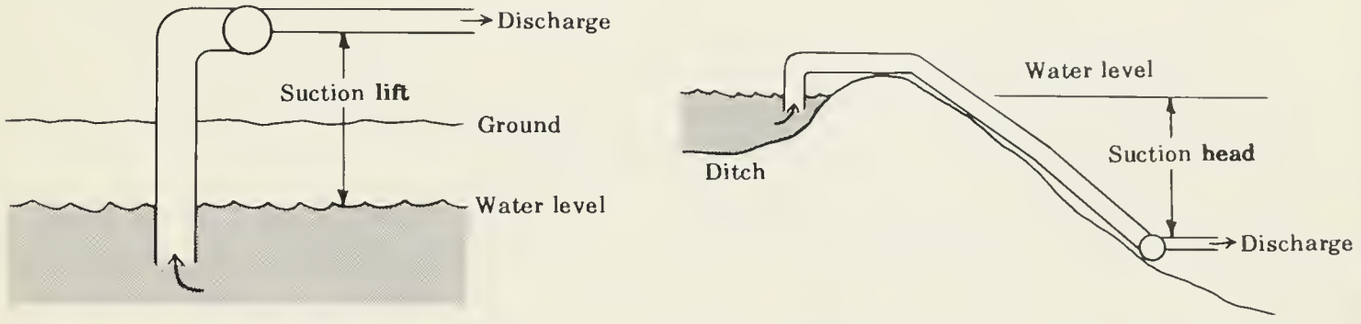


Figure 18. Suction Lift vs. Suction Head.

Add or subtract one of the above figures from pressure (first calculation) to get _____ **TDH(FEET)**

2) FIND FLOW RATE (GPM)

If your system has a flowmeter installed, read the GPM (gallons per minute) on the gauge. If the meter reads in CFS (cubic feet per second); convert that figure to GPM by multiplying CFS x 448.8 = _____ **GPM**

If you don't have a flowmeter and are using side-roll or hand-move sprinklers, you can do this:

Choose 4 operating sprinklers (the sprinklers should be 1/3 down the length of the lateral to estimate the average flow of each lateral).

Hold one end of the hose over a sprinkler head and put the other in the 5-gallon bucket.

Use your stopwatch to estimate the time to fill the bucket.

Repeat for the other 3 sprinklers.

Add up the total seconds:

Sprinkler 1 ____ sec
Sprinkler 2 ____ sec
Sprinkler 3 ____ sec
Sprinkler 4 ____ sec

TOTAL ____ SECONDS

Divide the total seconds by 4 (the number of sprinklers measured) to get the average number of seconds to fill the bucket:

$$\frac{\text{Total Seconds}}{4} = \text{____ Average Seconds}$$

Now, divide the number 300 (a conversion factor) by the average seconds to get GPM per sprinkler:

$$\frac{300}{\text{Average Seconds}} = \text{____ GPM/Sprinkler}$$

Multiply GPM per sprinkler by total number of operating sprinklers:

GPM/Sprinkler x Number of Sprinklers = _____ **GPM**

3) MEASURE ENERGY USE

Electricity

Locate the meter constant on the meter (marked K_h57.6 in figure 20).

Using the stopwatch, time the number of seconds it takes for the disk in the meter to make 10 revolutions.

Use this formula to find kilowatt hours used per hour (kWh/Hr):

$$\frac{3.6 \times \text{Revolutions} \times K_h}{\text{Seconds}} = \text{kWh/Hr}$$

Liquid Fuels

Record how many hours the engine operated and how much fuel was used (in gallons for diesel, gasoline, and propane, or cubic feet for natural gas). Then, divide the fuel usage by the number of hours of operation:

$$\frac{\text{Gals}}{\text{Hr}} \text{ or } \frac{\text{Cubic Feet}}{\text{Hr}}$$

4) FIND WATER HORSEPOWER (WHP)

Multiply the flow by the total dynamic head and divide by 3,960 (a conversion factor):

$$WHP = \frac{\text{Total GPM X TDH (FEET)}}{3{,}960}$$

5) DETERMINE PUMPING PLANT PERFORMANCE

Divide water horsepower by the energy used:

$$\text{Performance} = \frac{WHP}{kWh/Hr} \text{ or } \frac{WHP}{Gals/Hr} \text{ or } \frac{WHP}{Cu\ Ft/Hr}$$

6) SELECT PUMP EFFICIENCY

From table 6, select the expected efficiency of your pumping plant for its rated horsepower:

Table 6. Pump Efficiencies

Rated Motor Size (Hp)	Expected Efficiency (Percent)
3 to 5	66
7.5 to 10	68
15 to 30	69
40 to 60	72
75+	75

Note: These efficiencies are for older pumps in excellent condition. New pumps and used pumps in mild conditions of improved design will have higher efficiencies.

Source: Larry D. King, Bonneville Power Administration, Portland, OR.

7) DETERMINE PERFORMANCE CRITERIA

Now in table 7 locate the type of your pumping plant in the left column and follow the row across to the column reflecting the expected efficiency of your plant (taken from table 6).

Table 7. Irrigation Power Plant Performance Criteria
Pumping Plant Efficiency

	100%	75%	72%	69%	68%	66%
Diesel	16.7	12.53	12.02	11.52	11.36	11.02
Gasoline	11.5	8.63	8.28	7.94	7.82	7.59
Propane	9.2	6.90	6.62	6.35	6.26	6.07
Natural Gas[a]	82.2	61.65	59.18	56.71	55.89	54.25
Natural Gas[b]	88.9	66.68	64.00	61.34	60.45	58.67
Electricity	1.2	0.90	0.86	0.83	0.82	0.79

[a]Energy content of 925 Btu per cubic foot.
[b]Energy content of 1,000 Btu per cubic foot.
Note: Units are WHP per unit of fuel used per hour.
Adapted from Savings From Irrigation Pumping Plant Testing, 1985, Western Area Power Administration.

8) **FIND PERFORMANCE RATING**

To find out how your pumping plant's performance compares to the ideal, divide the figure obtained in step 5 by the one in step 7. The result is the performance rating of your plant **not its overall efficiency.**

$$\text{Performance Rating} = \frac{\text{Performance}}{\text{Performance Criteria}}$$

9) **DETERMINE EXCESS ENERGY USED**

To determine excess energy used per hour of operation, subtract the performance rating obtained in step 8 from 1.00, and multiply it by your hourly fuel usage:

Excess Energy Used/Hour = (1.00 - Performance Rating) x kWh/Hr

or

Excess Energy Used/Hour = (1.00 - Performance Rating) x Gal/Hr

or

Excess Energy Used/Hour = (1.00 - Performance Rating) x Cu Ft/Hr

---

EXAMPLE FOR CENTRIFUGAL PUMP

Based on the situation shown in figure 19 and some hypothetical calculations, this is how you would estimate the pump's efficiency.

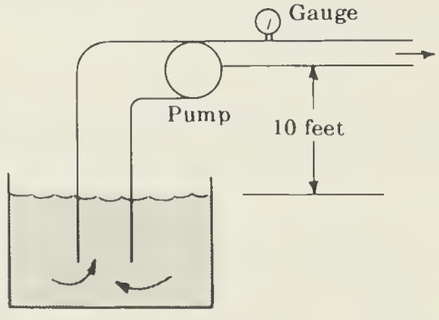


Figure 19. Electric Pumping Plant Configuration.

1) **FIND TOTAL DYNAMIC HEAD (TDH)**

Pressure from gauge = 60 PSI x 2.31	= 139 FEET
Height in Feet to center of pump from water surface	= + 10 FEET
	= **149 TDH**

2) FIND FLOW RATE (GPM)

No flowmeter so use 5-gallon bucket:

Sprinkler 1 - 73 sec
Sprinkler 2 - 69 sec
Sprinkler 3 - 71 sec
Sprinkler 4 - 72 sec

TOTAL 285 SECONDS

$\frac{285}{4}$ = 71.3 Average Seconds

$\frac{300}{71.3}$ = 4.2 GPM

200 operating sprinklers: 4.2 x 200 = 840 GPM or (estimated) = **850 GPM**

3) MEASURE ENERGY USE (Electricity)

The meter constant (K_h) is 57.6 (figure 20).

Meter disk required 45 seconds to make 10 revolutions.

Enter into formula to get kWh/hr:

$$\frac{3.6 \times (10)\ \text{Revolutions} \times (57.6)K_h}{45\ \text{Seconds}} = 46.1\ \text{kWh/Hr}$$

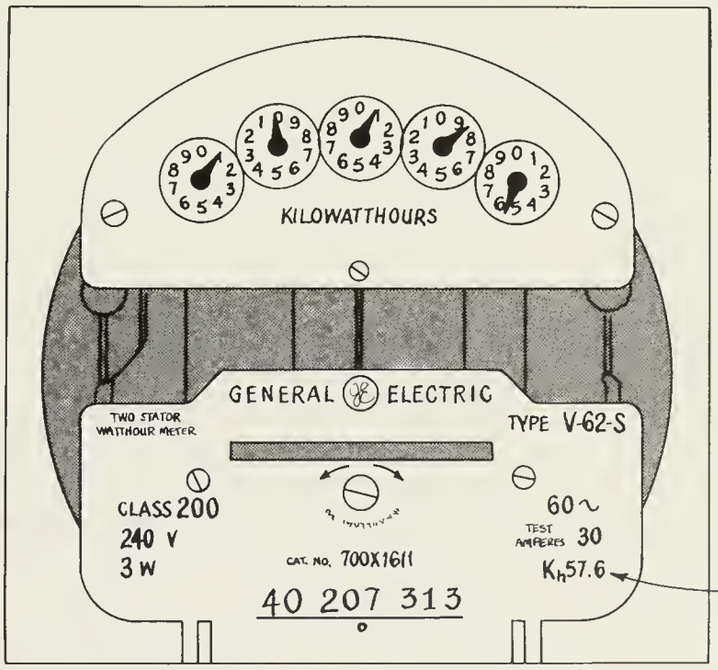


Figure 20. Electric Meter

4) FIND WATER HORSEPOWER (WHP)

$$\frac{850 \text{ GPM} \times 149 \text{ TDH (Feet)}}{3{,}960} = 32 \text{ WHP}$$

5) DETERMINE PUMPING PLANT PERFORMANCE

$$\text{Performance} = \frac{\text{WHP}}{\text{kWh/Hr}} \text{ or } \frac{32}{46.1} = .696 \text{ WHP per kilowatt hour per hour}$$

6) SELECT PUMP EFFICIENCY

From table 6, the expected efficiency of a 75 horsepower motor is 75 percent.

7) DETERMINE PERFORMANCE CRITERIA

Table 7 shows that the expected performance for an electric pump with an efficiency of 75 percent is 0.90.

8) FIND PERFORMANCE RATING

$$\text{Performance Rating} = \frac{\text{Performance}}{\text{Performance Criteria}} = \frac{.696}{.900} = 77.3 \text{ percent}$$

The pumping plant is operating at 77.3 percent of its **expected** efficiency of 75 percent. This means its actual efficiency is about 58 percent (0.773 x 0.75 = 0.58).

9) DETERMINE EXCESS ENERGY USED

To determine excess energy used per hour of operation, subtract the performance rating obtained in step 8 from 1.00, and multiply it by the hourly fuel usage:

(1.00-Performance Rating) x kWh/Hr = (1.00-0.773) x 46.1 = 10.46 kWh/Hr

This pump is using 10.46 kilowatt hours per hour more than necessary. If it were repaired or adjusted to its peak efficiency, it would save approximately $0.42 per hour of use (10.46 x $0.04) or $10.08 per 24-hour day based on a cost of $0.04 per kWh.

Sprinkler Systems

Water leaks and friction can easily increase energy use by 2 to 5 percent. You can reduce this waste by periodically checking your system from mainline through sprinkler heads. Here are some suggestions for increasing your system's efficiency.

MAINLINES/LATERALS

- Inspect mainlines for crushed pipes, holes, and split seams. Round out pipe ends with a wooden plug of the proper diameter, repair holes and seams or replace pipe.

- Use adequately sized mainline pipe. Pipe that is too small can inadvertently be left in place when the system is expanded. If the mainline pipe is not of the proper size for the extended system, major friction losses will occur. At 500 gallons per minute, an aluminum mainline 100 feet long will lose 19 feet of head in a 4-inch diameter pipe, but only 2 1/2 feet of head in a 6-inch diameter pipe.

- Minimize friction at mainline entrances and junctions through proper coupling.

Vigilante Rural Electric Cooperative in Dillon, under the Bonneville Power Administration's "Agricultural Conservation Program" has been performing free pumping plant tests for the last 6 years. On the ranch of Randall Smith at Glen, three pumps were recently checked out--two centrifugal pumps of 30 and 50 horsepower and one turbine of 75 horsepower. After these pumps had been repaired and adjusted, retesting showed that the turbine pump's efficiency had improved from 59 percent to 76.4 percent and its gallonage raised from 828 to 1,317. The efficiency of the two other pumping plants had increased by over 10 percent from 65 percent to 71.4 percent and 65 percent to 72 percent.

Smith said he was unaware of how his pumps' efficiencies had dropped. He had called the utility as a result of an ad he saw in the local newspaper. With 400 acres of alfalfa and grass hay under irrigation, he figures his power bill for irrigation should drop substantially.

- On laterals replace leaky, missing, or worn gaskets on couplers and valves.

- Check pipe, valves, risers, and nozzles for plugging from grass and other debris that can be sucked up through the intake line. Debris in lines can significantly reduce the spray pattern. In wheel-lines debris can hold drain valves open, dumping water out of the pipe.

- Inspect your system after each start-up. Check to see that nozzles aren't plugged, risers tipped, or sprinkler heads missing, and that sprinkler heads are rotating.

- Position sprinkler lines to minimize evaporation losses and nonuniform application due to local wind conditions.

- If possible, avoid laying sprinkler laterals uphill. With just a 2 percent slope over 1/4 mile, a 10 psi difference occurs between the two ends. A pressure difference between one end of a line and the other should not exceed 20 percent of the operating pressure. If it does, flow regulators should be used on each nozzle.

- Equip all end sprinklers that spray onto roads or other unfarmed areas of fields with spray deflectors or part-circle sprinkler heads to redirect water.

SPRINKLER HEADS

A very common practice is to replace a nozzle with one of a different size or model. A nozzle of the next larger size, however, can increase discharge by 21 to 24 percent at the same operating pressure. Soon the system is operating outside its original design range. (One system checked had 4 different nozzle sizes and water distribution varied as much as 76 percent.) By using the correct nozzles, the system will be operated at design pressures, and you won't be overwatering or underwatering some parts of your crop.

Most hand-lines and wheel-lines will use the same size nozzles at each sprinkler head location. If you have a center pivot system, ask your irrigation equipment supplier for a computer print-out of nozzle sizes for your system. The appropriate nozzle size for each sprinkler head on a center pivot depends on sprinkler head spacing. In some cases, a different size nozzle will be needed at each position.

A nozzle-wear survey showed 63 percent of the nozzles checked were worn enough to change the spray pattern. Wear enlarges nozzle holes which increases discharge, shortens the distance water is thrown, and increases droplet size. The result is wasted water and fertilizer and more potential for runoff. It also causes the pump to produce less pressure and could overload the motor or engine.

Nozzles can be checked easily using a drill bit. Select a new drill bit of the same nominal size as the nozzle aperture (the nozzle should have its aperture size printed on it). Insert the bit's shank into the nozzle. If you can barely fit the shank into the nozzle, it's okay. If the shank fits loosely, replace the nozzle. Table 8 shows how discharge increases with severity of wear.

Table 8. Sprinkler Discharge Observed Depending on Nozzle Wear.

Wear	Discharge With Drill Shank in Nozzle Hole	Percent More Water
Slight	Fine stream spraying water 5 to 8 feet	6
Moderate	Fine stream spraying water 10 to 15 feet	15
Heavy	Heavy stream spraying water 10 to 15 feet	20

Source: Dorrell C. Larsen, "How to Reduce Sprinkler Energy," Spudman, April, 1979.

Every 2 to 4 years, depending on the amount of silt or minerals in the water, operating time, and other wear-causing variables, check all sprinkler heads. Check the lower bearing washers for wear, the arms for pin wear and alignment and worn and broken springs. (To track sprinkler head age, spray a spot of paint on them when they are initially installed, then spray that same color on your shop wall and note the year.)

In field trips around the state, DNRC agricultural engineers have seen a number of irrigation systems with water erupting 40 feet or more from risers with missing sprinkler heads. These "geysers" are costing Montana growers dearly in wasted water and extra energy to pump the water. It is especially expensive for the grower with an electric pump based on demand charge billing. The extra kilowatts needed to pump the excess water sets the demand meter higher and plays havoc with the irrigator's power bill.

REPAIRING SPRINKLER HEAD WASHERS

The washer configurations will include one or two black rubber washers and another, often colored, wear washer. Compare the wear washer against a new one for thickness and replace if worn. Replace the black rubber washers whenever the wear washer is replaced. The black rubber washers do not generally wear, but should be compared for softness with a new washer. Replace if they have started to become brittle.

If your sprinkler heads don't have brass-to-galvanized fittings, wrap the threads with plumbers Teflon tape when replacing them. Petroleum based "pipe-dope" type compounds will cause early deterioration of the lower bearing seal rubber washers.

Surface Systems

The energy waste in flood irrigation is associated with the common set times of 12 or 24 hours in Montana. While these times suit the operator's hours, they often put too much water on the crop, leaching fertilizer beyond the reach of the plant, increasing pumping costs, and causing runoff. Although sprinkler systems usually can be designed around set times, surface systems can only be to a limited extent. The best hope for increased efficiency in surface irrigation is through automated systems.

The following suggestions for improving surface irrigation are just that--suggestions. Whether they will work for you depends on your soil, your crop, your equipment, and your pocketbook.

Cutback method. A non-automated, but effective method for applying water uniformly and reducing tailwater losses is the cutback method. At the beginning of the irrigation cycle, two siphon tubes are used at the head of the furrow. The two tubes supply enough water initially to push the water down the furrow faster, limiting the amount that soaks in at the upper end. One tube is then removed to reduce the amount of water being supplied so both ends get about the same amount of water without saturating the upper end or causing excess runoff at the lower end. The greater labor requirement and closer management can make this unfeasible for many farmers.

Tailwater Recovery. A return flow or reuse system reduces tailwater losses. A small reservoir (pit) captures surface runoff and a pump-back system uses the water to irrigate other land or to supplement the flow of water during the start of each subsequent irrigation set. The net result is more uniform irrigation and considerable saving of water and energy. (NOTE: Make sure that water rights allow for application of the reuse water to land other than originally specified.)

Land Leveling. High surface irrigation efficiencies can be obtained when furrows, graded borders, or level borders are installed in fields with uniform grades.

Surge-flow. One of the most effective automated surface irrigation methods for Montana is surge-flow irrigation which automatically alternates the water from one set of furrows or bordered area to another until the crop gets the water needed. The surging action caused by turning the water on and off into an area smooths the soil, decreasing its water intake rate and causing the stream to advance up to twice as fast as with regular irrigation. With careful management, efficiencies can be dramatically increased. Reasonably priced computer-controlled valves are now available that make this method very practical in Montana, especially where gated pipe is used.

Ross Peace and his son Alan installed a surge-flow gated pipe system a couple of years ago for irrigating their malting barley crop on the Fairfield Bench. Last year they had water savings of up to 40 percent and no power costs for pumping. The surge-flow system also has resulted in significant labor savings. It takes only 20 percent of the man-hours that the previous contour ditch irrigation required.

From an open ditch, water is carried in a 10-inch pipe down a drop of about 10 feet to 8-inch gated pipe. The pipe lies across the upper end of a 1,000-foot field with a 3 percent slope. The gravity flow system develops up to 3 pounds of pressure. A surge valve is installed at the center of the 1,500 foot section of gated pipe, where the mainline connects.

Every hour the surge valve switches water from left to right, right to left, watering 150-foot field sections through a group of 75 to 90 open gates in the pipe. Every 12 hours a new group of 1- by 3-inch gates is opened on each side of the surge valve.

Using a Paul Brown Probe to check soil moisture Peace's son has found he's getting 3 to 3 1/2 feet depth at the upper end of the field, and 2 to 2 1/2 feet at the lower end. They have no trouble with tailwater or fertilizer leaching.

Surge flow valve operated by small 12-volt battery.

Water emerging from gates in the pipe.

In Rosebud County, the Conservation District and one of their cooperators, Scott and Clara Giesick, have undertaken a pilot project to test the feasibility of surge-flow irrigation on alfalfa. Using gated pipe, they are irrigating alfalfa in a border-dike system. A solar panel operates a timer that controls a surge valve in the pipe, alternately switching water from one bordered area to another. As a result, they are hoping to achieve more even water distribution throughout the field, avoid supersaturation at the upper end, and get less tailwater. Preliminary estimates in other areas show water savings from surge-flow irrigation of 35 to 45 percent.

Small photovoltaic panel provides power to timer.

Cablegation. An automated system being used in Idaho is feasible for Montana. Cablegation uses surface gated pipe, or buried pipe with risers stretching across a carefully graded downward slope. A plug in the pipe travels at a controlled rate of speed down the pipe. Water only flows through those holes that are in the section of the pipe filled with water, which changes as the plug moves slowly forward. Cablegation is being effectively used for furrows and borders.

Automated Air Cushion Valves. Buried pipe with alfalfa valve risers can be automated with "air cushion" valves. These valves are actuated by a portable air tank equipped with a timer. The water from the valve can go either into gated pipe or directly into borders.

Automatic Gated Ditches. A system of concrete ditches with timer-actuated gates is being used successfully on fields with graded borders on the Fairfield Bench in Montana. With careful management, set times are optimized to minimize deep percolation and runoff.

Scheduling

Besides curbing losses at the pumping plant and distribution system, better scheduling of water application can pay off handsomely in fertilizer savings, reduced pumping costs and water use, and often improved crop quality. Experienced irrigators are often surprised to learn they are irrigating too frequently, and are applying too much water.

Although methods vary, the main idea of scheduling is to calculate how much water in the root zone is available to the plant, and when you should irrigate again. For scheduling to work, you'll need to know your soil's waterholding capability, the crop's water requirements, and how to determine soil moisture.

Soil Waterholding Capacity. How well your soil absorbs and holds moisture is the most important factor in how much water you apply and how often. A fine sandy loam will have a high intake rate and low waterholding capacity, whereas a clay type soil will have a low intake rate, with high water retention. The Cooperative Extension Service has bulletins on the water holding capacity of soils, and how to estimate the amount of water your system is delivering. The Soil Conservation Service also has information on waterholding capacity and intake rates for many localities in Montana.

Crop Requirements. The amount of moisture a crop withdraws depends upon the type of crop, its stage of growth, and climatic area. You can get charts from the Cooperative Extension Service or Soil Conservation Service that show crop root-zone depths, estimated water requirements at different stages of growth, and climatic area irrigation guides.

Soil Tests. Physically checking soil moisture tells you the water level and whether it's time to irrigate. Soil moisture tests are also used in other

scheduling methods as a beginning point for estimating water depletion.

Some soil moisture detection devices are soil probes, soil augers, tubes, tile spades, and more elaborate devices such as the neutron probe, gamma probe, tensiometers, and electrical resistance blocks. The Cooperative Extension Service has a number of bulletins explaining the use of these methods. Your local SCS district conservationist can also show you how to use a probe or auger and determine water deficit by feel and appearance.

Evaporation Pans. The evaporation pan or washtub method for scheduling irrigation is relatively inexpensive and easy to use. This method relates the amount of water evaporating from a tub in the field to the amount of water being taken from the soil by the plant. Your local cooperative extension agent can provide you with publications on using evaporation tubs to schedule irrigations.

Checkbook Method. This irrigation-scheduling method operates in much the same way as a checking account record. You keep a record of the moisture in the soil, then estimate when the "account" (the soil) needs its next "deposit" (irrigation).

By recording daily maximum temperature, crop water use, amount of rain, net amount of irrigation water applied, along with other information, you'll know when the soil moisture is getting low. Using the checkbook method you can predict when the next irrigation will be required, and have time to prepare for it. Your local cooperative extension agent or SCS offices can help you set up a checkbook irrigation method.

"CONSUMPT." Instead of tracking your crops' water use (through an evaporation tub or estimating from crop growth charts) to enter into your checkbook scheduling method, you can use the data collected by a network of observers in several irrigated areas of Montana. The data are received by the Cooperative Extension Service and delivered to newspapers, radio and television stations.

"SCHEDULE." A Montana State University computer program named "SCHEDULE" has become a standard part of the irrigation process

During the 1986 growing season, three irrigators and one dryland farmer monitored the soil moisture of their fields of sugar beets, alfalfa, and small grain with a neutron probe. The instrument's accuracy and direct readout in inches of water per foot resulted in significant savings of water, energy, and time as well as increased yields.

The probe, purchased by the Roosevelt County Conservation District for use by the Soil Conservation Service at Culbertson, was also used with 9 irrigators in the Integrated Pest Management program of Montana State University Cooperative Extension Service.

Dick Iversen, District Conservationist, said he, Paul Finnicum, SCS student trainee, and Roger Ashley, Cooperative Extension Agent, attended a 2-day training course to become licensed operators of the probe. Once they had installed the steel access tubes, 1 or 2 to a field, they made weekly visits to the sites with the farmers to take the moisture readings.

On the Fort Peck Irrigation Project at Wolf Point, cooperators who followed irrigation recommendations derived from the use of the neutron moisture probe harvested 10 to 25 bushels of small grains per acre more than fields where this irrigation scheduling tool was not used.

On the average, sprinkler irrigation cooperators were able to save two irrigation operations. Other benefits included reduction in disease and elimination of fertilizer leaching below the root zone.

Dryland operators used neutron moisture readings to determine early fertilizer applications of ammonium nitrate for winter wheat. By knowing the exact amount of moisture in the soil the grower could calculate the amount of fertilizer to apply for optimum yield.

for many farmers and ranchers in Montana. Soil characteristics, crop, planting dates, climate and other data are entered into the computer once. By updating the computer with current soil status (how much water remains), you'll be told when to plan your next irrigation. The program comes on a floppy disk for those with home computers. Or, it can be accessed from a terminal in the Cooperative Extension office. A bulletin available from your local extension office has the details.

Converting Systems

In the next few pages you'll find suggestions for energy-conserving irrigation methods. Although energy-efficient systems are important, decisions on changes in irrigation need to be made carefully with several factors in mind.

In most cases soil type is the deciding factor--its waterholding capacity and intake characteristics, and the type of crops it will grow. In some cases the ground slope or roughness of a site can make surface irrigation impossible without excessive amounts of surface leveling. Other considerations are available water flow rates, fertilizer and herbicide application methods, temperature and wind patterns, water quality, and, most important, crop needs. Labor availability and capability, of course, enter into system selection.

In Montana many side-roll and hand-move sprinkler systems are putting on too much water. Sets of 12 hours or 24 hours are used when much shorter set times would be adequate. The same is true of many pumped surface systems. In these cases, the greatest energy loss can be extra pumping time. If set times can't be changed, it can pay off to redesign the system to fit set needs.

Agricultural engineering services, local SCS district conservationists or cooperative extension agents can help you design and select the proper irrigation system for maximum payback on your site.

Limited Irrigation. You might reduce pumping costs by eliminating unnecessary irrigation. Experiments have shown that irrigations after the soft dough stage on grain crops have little or no effect on crop yield or quality. When crops are irrigated only during critical growth stages, reduced pumping costs usually result in higher profits even though yield may be somewhat reduced. Timing, of course, is of utmost importance. For further information check the list of Cooperative Extension Service publications.

Gravity Flow. Eliminate energy costs by harnessing gravity. Many areas in Montana have supply ditches at high enough elevations to generate the pressure needed for sprinkler irrigation. Often a group of neighbors can cooperate in installing a group pipeline to supply several farms. The Soil Conservation Service provides technical assistance to analyze such projects.

A gravity pressure system for the West Bench Irrigation District near Dillon irrigates 6,000 acres of hay and small grain crops through 30 miles of pipe and wheel- and hand-lines. Installed in 1980 with the help of the Soil Conservation Service and Bureau of Reclamation, the system will be paid off in 25 years. Garth Taylor, manager of the district, says that because they have no pumping costs, the water will be "free" after that. In the meantime, they have had a fourfold increase in production. Taylor said the last part of the season always found them short of water before the system was installed. Confining the water in the pipes rather than open ditches reduces water losses and avoids silt problems.

Jack Perkins, a cattle rancher near Deer Lodge who also raises small grains and alfalfa, irrigates 327 acres with gravity sprinkler systems. Using both hand-lines and wheel-lines, he averages 35 psi at the upper end and 80 at the bottom end of one system, and 35 to 95 psi on the other.

His maintenance is almost nothing--maybe $200 per year. Jack compares this with a small pump his son uses on one section that has maintenance costs of $500 to $600 a year--not including the power used.

Perkins says they flood irrigated part of the land, but left most of it as dry land before installing his gravity feed system. There simply wasn't enough water to do it all. Now he has plenty of water most years, better water distribution, better crops and higher yields at virtually no cost.

John Bouma grows alfalfa near Fairfield. His fields are on the end of an irrigation canal. Because he was nearly drowning his crop by flood irrigating heavy soil, Bouma wanted to redo his irrigation system. The irrigation district wanted to close the last 3 miles of the canal due to extensive seepage and maintenance problems.

Together they installed a gravity flow system to 135 acres, which took care of both their problems. Dropping about 125 feet from the canal to the field, 1/2 mile of buried 18-inch pipe and another 1/2 mile of 10-inch buried pipe produce up to 57 pounds of pressure to center pivot sprinklers.

Bouma and his neighbor were able to reduce pumping costs in a second system by extending the 10-inch pipe another 1/2 mile. The pipe delivers water to a pump at 20 pounds of pressure. The pump boosts the pressure to 45 psi to run wheel-lines on another 110 acres.

When Gary Pearson of Fairfield decided to switch from flood to sprinkler irrigation, he chose a gravity flow system. From the Greenfield Irrigation District canal, 1.7 miles of pipe run to a center pivot and wheel-lines that water 300 acres. He has a 10 horsepower booster pump on the 2 sets of wheel-lines but says he may not need it. His hired man didn't turn on the pumps and the sprinklers watered just fine without it.

Last year his power costs for the booster pumps and to drive the pivot were $340. He estimates he's saving 50 percent or more in water, and his malting barley yield has increased by 20 bushels per acre.

Not all successful gravity feed systems cover large areas. Near Divide, Carl Johnson irrigates 25 acres of alfalfa, running his system from a ditch off Tucker Creek. He says the elevation drop of 90 feet to his field is plenty to run 1,300 feet of 6-inch mainline with two laterals supporting 18 sprinklers each. He gets 34 psi at his nozzles. A screen over the intake pipe keeps the trash out of the lines.

Johnson's previous flood irrigation system wasn't doing the job. He was using too much water and unlevel fields caused high spots to be missed. He engineered the system with help from the Soil Conservation Service.

Members of the East Bench Irrigation District near Twin Bridges decided they had to do something about their power costs or go out of business. Their solution was to begin switching 25,000 acres over to gravity feed irrigation. So far, 23 miles of pipe ranging in size from 42-inches to 6-inches have been installed to water hay and grain on 6,500 acres.

The long 3 percent slope from canal to fields provides plenty of pressure for all types of sprinklers: hand-lines, siderolls, center pivots. And the size of the pipe ensures that the crops are watered adequately under the most extreme conditions. Dick Kennedy, manager of the project, says a successful system can't be designed according to long-range averages. In their area "averages" show that 6 to 6 1/2 gallons per minute is adequate; but often they'll get 2 to 3 weeks of hot, dry, windy weather. When that happens in conjunction with light soils, the irrigators need 8 1/2 gallons per minute. It takes larger pipe, but without it, crops can be lost overnight. He also emphasized the importance of a good screen. They have installed a screen that rotates intermittently due to head differential or a preset time. As material collects, a strong water spray plus a conveyor belt removes particles.

When the project began during the time of high inflation, it was expected the payback would begin after the first 3 or 4 years of operation. With the cost for pipe not as high as predicted, but with power costs still running between $15 to $17 per acre, Dick says they may see a more immediate payback.

Lining irrigation ditches with concrete, bentonite, plastic membrane, or otherwise preventing loss of water due to weed growth and seepage can save water and energy. Replacing open ditches with pipe can reduce water losses and pumping costs.

Trickle/Drip. Experiments in eastern Washington showed that orchards can be irrigated with 1/25th the amount of water used with conventional sprinkler or surface methods. Drip irrigation discharges water slowly at low pressure through a small opening directly to the root system of the tree or vine, without excess or runoff. In many cases, substantially increased yields can be obtained through trickle/drip irrigation.

Multiuse Overhead System. Using a fixed sprinkler system for irrigation, cooling, frost protection, and the application of fertilizer and chemicals can save energy in orchards or vineyards.

Low Pressure. Low pressure sprinklers have the same basic characteristics of any other sprinkler system, but they generally operate best in the range of 10 to 30 psi. The sprinklers are fitted with low pressure nozzles to help distribute the water more efficiently. When converting from a high pressure irrigation system to one of low pressure, the pump must be modified to realize the full energy savings potential of a low pressure system.

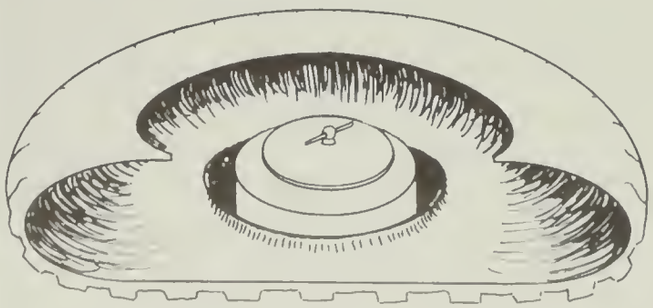
When converting center pivot sprinkler systems to low pressure, the sprinkler spacing must be reduced to maintain uniformity. The maximum spacing on low pressure is 10 feet. This requirement is paramount when drop tubes are used.

Lloyd Meland, who grows irrigated wheat near Vaughn, was having a lot of trouble with his ditches washing out, grass growing in them, and silting. He thought about getting a center pivot or wheel-line, but didn't want to pay the expense for a pump and the pumping costs. His solution was to replace the ditches with an underground pipeline.

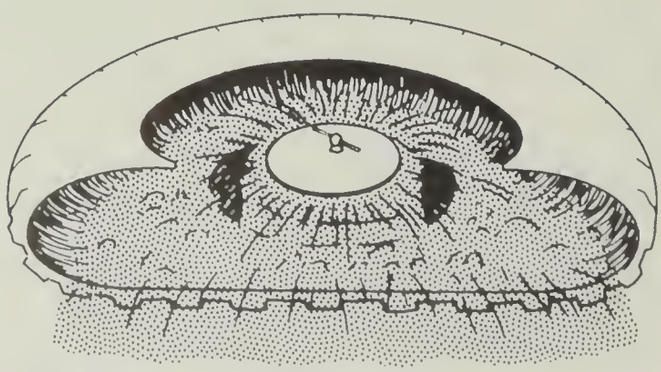
From the main canal, he installed 18-inch pipe for about 400 feet, then another 480 feet of 15-inch pipe. Along the entire pipeline he has risers with alfalfa valves. To redirect the 360 degree spray from the valves towards his field, he collected old combine tires and laid them behind the valves. With the bead removed and a section of the tire cut out that faces the field, water collects inside the tire, runs out the opening and down the field. He irrigates out of five alfalfa valves at one time, opened 1 1/2 turns, and can irrigate 53 acres in about 30 hours.

He also added 1,980 feet of 12-inch pipe along the east side of the field, added two alfalfa valves to deliver the water to the southeast corner and to irrigate another 30 acres south of there. This pipeline completely eliminated all soil erosion where open ditches used to be.

Meland estimates a 10-year payback because of the simplicity of the system. By using the old tires he didn't have to buy expensive hydrants for the valves. A side benefit, he says, is that once he got rid of his ditches his alkaline and seep problems pretty much disappeared. And, he's getting better water distribution with the alfalfa valves.



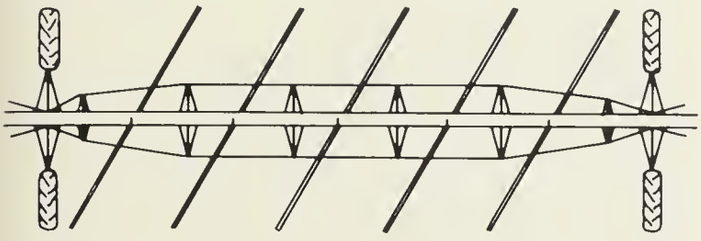
Empty alfalfa valve and combine tire with bead removed.



Alfalfa valve opened 1/2 turn. 1 1/2 turns will fill tire.

An easy way to do this is to use booms angled as illustrated in figure 21 (not perpendicular) to the center pivot lateral. This has the effect of maintaining uniformity and increasing the area of application which minimizes runoff.

TOP VIEW



SIDE VIEW

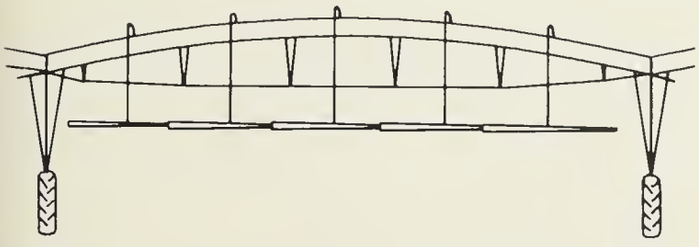


Figure 21. Angled Booms on Low-Pressure Center Pivot Sprinklers.

When using drop tubes, nozzle height should not fall below 3 feet. As nozzle height increases, however, spray losses increase. Spray losses for spray nozzles are about 3 percent at 3-foot elevation, 6 percent at 6-foot elevation, and 11 percent at 12 to 15-foot elevation. Also, it has been found that operating pressures below 10 psi are not adequate in most cases. The area of application is too small causing runoff; and uniformity declines.

Low pressure conversion for hand-lines may require offsets to uniformly distribute water as illustrated in figure 22.

Low pressure requires pressure/flow regulation. Newer models with surge protection are more reliable than older models, although their long-term durability is unknown. As long as operating pressure in the lateral is less than 80 psi, the newer regulators don't have to be used in series because they are able to handle such variation. However, if pressures exceed 80 psi, the regulators will have to be operated in series to have adequate flow, minimum pressure loss, and surge protection.

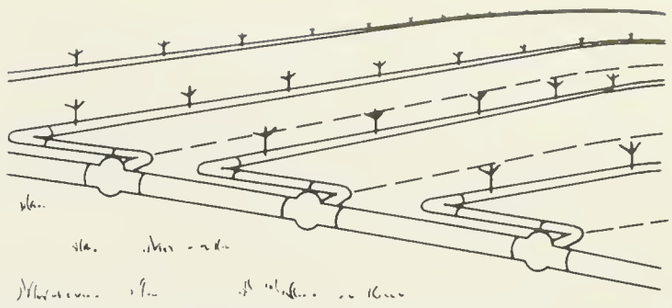


Figure 22. Offsets for Low-Pressure Hand-Line Sprinklers. (Reprinted from Offsets for Stationary Sprinkler Systems, Bonneville Power Administration)

Because of the series of trade-offs in converting to a low-pressure system, a good cost-benefit analysis should be made before taking this action. (Your local SCS district conservationist or cooperative extension agent can help you.)

Modifying part of a system can be the answer. Present center-pivot systems require high pressures because of the large "gun" type sprinkler at the end of the system. This gun irrigates an additional area beyond the end of the system, and requires a higher pressure than the smaller sprinklers on the main line. If the system could be modified by adding a small booster pump to supply water at high pressure directly to the gun, additional pressure reduction in the main system is possible. This can result in energy savings of over 40 percent when the total dynamic head is 150 feet, but only 20 percent if the total dynamic head is 300 feet.

Automatic Controls. Radio controls on center pivot systems are especially useful where pivots are scattered over a large area or where workers and equipment are separated by long distances. The controls can report the speed and pressure of the system, change its direction, turn the pump on or off, and perform functions by remote control, saving fuel and labor.

Wind Power. During the twenties and early thirties, millions of wind-energy systems were used on farms. Depending on the location, wind-powered irrigation systems can be just as competitive today.

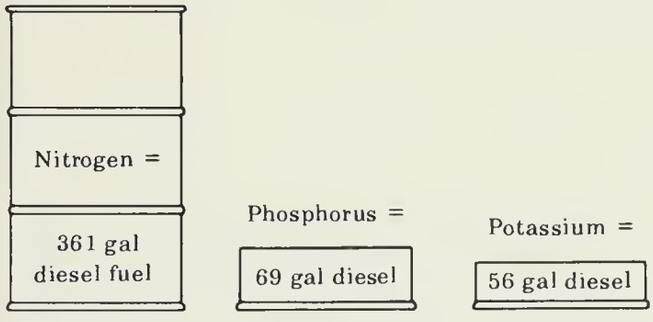
Alternative Crops. Growing crops that have a lower water requirement could translate into energy savings. Such crops might include fababean, garbanzo bean, safflower, and native grasses. These crops are the most promising for energy conservation in Montana based on current farm equipment and practices, seed costs, weed control and fertilization, and market.

CHAPTER 3

Trimming Crop Chemicals

A large part of the Montana farmer's operating budget is directed to feeding crops, mostly with commercial fertilizers. In 1984, 462,993 tons of commercial fertilizer were applied to Montana cropland. Primary nutrients represented in this tonnage were: nitrogen--137,362, phosphorus--88,044, and potassium--13,676. These nutrients, particularly nitrogen, require large amounts of energy to manufacture (see figure 23). The energy used to produce these chemicals represents the equivalent of 56,428,574 gallons of diesel.

Each year Montana producers spend approximately $25,000,000 on herbicides. These costs for chemicals, combined with the fuel to apply them, represent a considerable outlay. If you can get by with less fertilizer and pesticide, you'll not only save money, but energy as well, even though indirectly. Also, the fewer chemicals used, the less vulnerable you'll be to the ups and downs of energy supplies and costs.



Note: Nitrogen requires 26,000/BTU/LB; phosphorus (P_2O_5) requires 5,000 BTU/LB; potassium (K_2O) requires 4,000/BTU/LB. Diesel fuel has a heat energy of 136,000 BTU/GALLON.

Figure 23. Energy Required to Produce One Ton of Fertilizer. (Reprinted from Fuels for Agriculture, Wyoming Energy Conservation Office. Data source: The Fertilizer Institute)

Because of the variables involved in chemical use, a list of "things to do to save money" isn't possible. What you will find in this chapter is a collection of ideas for reducing chemical use by:

- Tailoring fertilizer to crop
- Proper timing and placement of fertilizer
- Growing green manure
- Pest prevention
- Integrated pest control
- Maintaining spray equipment

To implement the suggestions, you'll need more information from your local cooperative extension agent, or SCS office.

Focusing on Fertility

Consider the following management practices to reduce your commercial fertilizer use.

RECORD KEEPING

Individual field records are invaluable for comparing fertilizing and cropping history. Records will tell you the optimum nutrient level in the soil for the best yield. When practical, treat smaller areas--not just fields, but areas within fields--according to their needs.

BEST NET

Can you make more with fewer bushels or bales? That's a good possibility given the high cost of fertilizer. Calculate the yield history of your fields in response to different levels of fertilizer, the expected price for your crop, and the cost of the

fertilizer. You will find a certain point where the yield gained won't pay for the cost of the added chemical. Table 9 calculates a hypothetical net return for barley where the last 40 lb of N increases the yield by 2 bushels for an additional income of $4.80 but at a cost of $8.00.

Table 9. Calculating Fertilizer Net Return

Nitrogen @ 20 cents/lb		Barley @ $2.40/bushel	
Lb/Acre	$/Acre Added Cost	Total Yield Per Acre	$/Acre Increased or Added Return
0	0	61	0
40	8.00	76	36.00
80	8.00	82	14.40
120	8.00	84	4.80

TESTING

An annual soil test can return big dividends for the few dollars and hours invested. Unknowingly, you might be replenishing the soil with the wrong combination of nutrients. Or below-normal yields may have left fertilizer in the soil which can be used by the next crop.

Choose a quality laboratory familiar with Montana soil, crops, and climate. The proper procedures for soil testing can be obtained from the lab of your choice.

A plant tissue test later in the season can determine the effectiveness of your fertilizing program. Leaf analysis can reveal deficiencies such as zinc, iron, boron, and other elements that may be hampering production. Depending on the crop, it is possible a nutrient deficiency detected early enough can be remedied through additional fertilizer application. Your local cooperative extension agent has information on soil and tissue testing.

Soil and tissue testing are an inherent part of Chip Fosland's farm management program in Daniels County. Every year he tests the soil and applies the fertilizer that's necessary. Later in the growing season, a tissue test tells him whether the plants are taking up the fertilizer. One of the surprising things he found was that although one area of his farm tested high in soil potassium, a tissue test showed plants were not taking it up. In view of this, he applied a small amount of potassium with the seed. Fosland says when you consider the possibility of over- or under-fertilizing and the low yields that may follow, annual soil and tissue testing together are very inexpensive.

John Bouma, who grows alfalfa near Fairfield, depends on an annual soil test to determine phosphorus buildup. This year the test showed enough phosphorus left so that he could omit its application.

TIMING AND PLACEMENT

Timing and placement of fertilizer are critical to maximizing its benefit. The best timing depends on the soil type, climate, crop, and particular nutrient in question. Nitrogen is particularly vulnerable to loss through leaching, dissipation into the atmosphere, or break-down by microorganisms. Check the many publications the Cooperative Extension Service has on fertilizer application and recommended planting varieties, dates, and seeding rates in Montana.

Generally, you can get more out of your fertilizer by:

- Selecting the best seed variety based on your soil, precipitation, and climate.
- Planting during the recommended range of dates for crop and area. Past these dates, response to the same amount of fertilizer is lower.
- Fertilizing nearest to planting time for most crops.
- Tilling broadcast fertilizers into the soil to prevent nutrients from escaping into the air.
- Injecting or banding nitrogen into the soil to cut nutrient loss by wind or sudden intensive rains.
- Avoiding excessive irrigation immediately after applying nitrogen to avoid leaching below the root zone.
- Checking to see that broadcast dry bulk-blended fertilizer application is uniform.

- Instead of broadcasting, use banding (applying nutrients below or to one side of crops while seeding) to use less fertilizer per acre.
- Reducing the number of trips across a field, especially when the soil is wet, and controlling wheel traffic to reduce compaction, which restricts the root's ability to penetrate and absorb nutrients.
- Contour planting, terracing, and managing irrigation and soil drainage to prevent fertilizer losses due to runoff from water.

REDUCING MANUFACTURED FERTILIZER NEED

Legume cover crops such as sweetclover, alfalfa, vetch, birdsfoot trefoil, black medic, winter peas, and beans add nitrogen to the soil, either by fixation or through mineralization as the plant decomposes. This nitrogen is then available for the next year's crop. Because a green manure cover crop will take some of the soil moisture, it is more adapted to irrigated land, or dryland areas of Montana where soil moisture levels are replenished with winter precipitation.

Compost (manure, sewage sludge, and plant residues) can also reduce manufactured fertilizer requirements.

Shelterbelts and grass barriers minimize wind erosion, conserve water, and minimize the loss of nutrients.

Shallow rooted crops (peas, beans, lentils, grasses) rotated with deep rooted crops (alfalfa) use nutrients at different levels in the soil.

Near Sidney, Agricultural Research Service scientists found that 5-foot high snow barriers of grass trapped enough additional moisture to permit annual cropping, and that the extra moisture resulted in more efficient fertilizer use. Tall wheatgrass planted in 2 north-south rows 36 inches apart formed the barriers, which were separated by 48-foot strips for cropping.

Jim Sims, Professor of Soil Science at Montana State University, is experimenting with various green manure crops. One promising method for Montana is Australian "ley farming," a method of sustainable dryland cereal production.

The first year the grower plants a legume in the spring, turns it under in late summer, then seeds the cereal crop that fall or the following spring. In the fall of the second year, the cereal crop is harvested, and the legume, which reseeds itself, is allowed to grow to replenish the nitrogen. In the summer of the third year the legume is again turned under and the cereal crop seeded that fall or the following spring. It's possible to sustain the cycle with the legume reseeding itself for up to 20 years.

The legume Sims uses in Montana is "George" black medic, followed by spring wheat. In a 7-year period, Sims grew 3 cycles of medic and spring wheat. On the first cycle, the medic-wheat yield was 52 bushels of wheat per acre compared to 27 bushels per acre on fallow ground. The second and third cycles gave improved yields, but not quite that dramatic.

The medic isn't deep rooted and doesn't take much water. In fact, winter precipitation in the Bozeman area replaced everything the medic used. Medic is self-pollinating so doesn't require bees as alfalfa does.

Fababeans (also known as fava beans) are another area of research. Sims says that in areas of adequate moisture, dryland fababeans can add 100 pounds of nitrogen per acre to the soil if used as a green manure crop. If harvested as a bean crop, its contribution is around 30 to 40 pounds of nitrogen.

Many other legumes could be chosen by Montana farmers, among them are Austrian winter pea (spring seeded), lentil, chickpea (garbanzo bean), green or yellow pea, sweetclover, and dry bean. Availability and cost of seed are important factors for producers to consider.

In the Kalispell area, Dale Sonstelie is one of about 25 farmers who are growing their own nitrogen. For the past 5 or 6 years Sonstelie has been inserting an annual legume, either spring peas or lentils, into his wheat and barley rotations. He says it has helped lower fertilizer costs and break up disease cycles in his small grains.

One year he made a side-by-side comparison of small grains seeded on fallow with small grains seeded on land planted the previous year to an annual legume. He found no differences in yields of wheat following either lentils or summer fallow. However, barley planted on lentil ground produced 20 bushels more per acre than barley seeded on stubble.

Leon Welty, an agronomist with the Northwestern Agricultural Research Center in Kalispell, directed a recently completed project to document the nitrogen-saving benefits of annual legumes.

The first year, the researchers planted lentils, spring peas, winter peas, chickpeas and fababeans at Bozeman and at Huntley. They also planted pinto beans at Bozeman and soybeans at Huntley. The next year they seeded the ground to barley.

Results indicate the annual legumes cut the costs of fertilizer needed to produce optimum small grains yields under normal conditions by $19 per acre and by $9 per acre under drought conditions.

Doing Battle With Pests

Commercial pesticides protect crops from insects, weeds, and diseases. Like fertilizer, pesticides require large amounts of energy for their production, and any reduction in their use will indirectly save energy. In addition to the chemicals themselves, costs for machinery, labor, and fuel to run the equipment for applying pesticides.

Traditional pesticide use in agriculture is looked upon as preventive medicine. Many farmers feel that routine application is necessary just in case a pest problem develops. Integrated pest management, on the other hand, uses a coordinated control program that combines cultural practices with chemicals, as illustrated in figure 24. See if some of the pest management strategies can reduce your pesticide use.

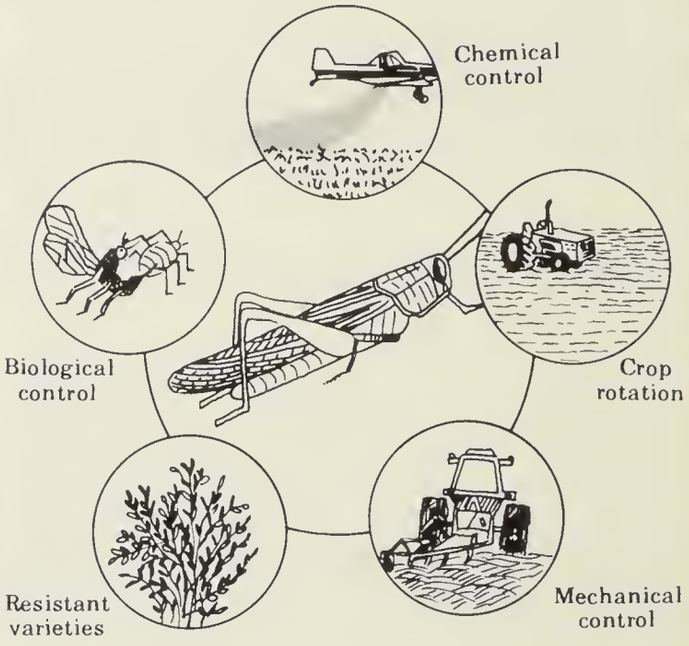


Figure 24. Integrated Pest Management Controls.

Prevention is the Least Expensive Solution to a Pest Problem. A number of successful methods are:

- Using certified seed, disease-free seed, and seed specially treated to prevent pest damage.
- Managing farm animal manure and feed (hay without weeds), machinery, and irrigation and drainage waters to keep weed seeds from spreading.
- Planting at optimum soil temperatures to ensure the crop will quickly grow and form a canopy to shade out weeds.
- Seeding beneficial plants on idle land or mowing weeds to allow natural introduction of more desirable plants.
- Seeding a cover crop or mulch to compete with weeds as well as return organic matter to the soil.
- Selecting forage seed for competition with weeds. If deep-rooted weeds are invading, seed

deep-rooted forage to compete against the weed for soil moisture.

- Delaying spring grazing to let desirable forage use the soil moisture as well as shade out the weeds.

- Rotating grazing pastures to prevent overgrazing of desirable plants.

Crop Rotation Helps Control Pest Problems. Pests that are attracted to one crop might not like a different crop. For example, a wheat-barley rotation can be used as a control measure against root rot of wheat. Experiments in eastern Montana suggest that growing safflower on wheat-fallowed land could help break weed invasions. Certain crop residues can release substances toxic to other plants, a process known as "allelopathy." These natural "herbicides" have the potential to inhibit the germination and growth of undesirable plants.

Chip Fosland, who is using reduced till in his dryland farming operation in Daniels County says crop rotations help minimize his chemical use. Grass weeds are by far the most costly to control, and certain crops provide a less favorable environment for grasses. By rotating winter wheat with spring wheat and oil seed crops, he obtains better control with less chemical. He emphasizes that timing is essential to get the most control for the smallest amount of chemical. Fosland has found the very best weed control is a vigorously growing crop.

Predators and Parasites Can Destroy Pests. A parasitic wasp has been used successfully in Montana to kill alfalfa weevil larvae, as has Nosema locustae to subdue grasshoppers.

Montana farmers and ranchers are finding the best control of leafy spurge, an aggressive perennial weed, is sheep rather than chemicals, particularly in heavily invested pastures. The leafy spurge hawkmoth and a root-boring beetle also show promise of subduing leafy spurge.

Pest Maps Help Avoid Trouble. Repeated use of the same or chemically similar pesticides can cause resistant varieties of insects and plants to form after a period of time. Use a distribution map to show what pests are in what fields and the chemical used for each. Maps will also remind you of where pest problems might occur in the future.

Control is an Economic Decision. Scout your fields. Check for weed populations. Set insect traps. Spray only if the pest is apparent (or will expand) in such quantities as to cause a greater yield reduction than the cost of the spray and its application, keeping in mind Montana's weed control law for noxious weeds.

If control is in order, then use the best method considering the pest's life cycle, the weather, and other factors. And be sure to use the right chemical for the job. While this seems like common sense, often a pest is misidentified or the pesticide label isn't read closely. The result is a waste of pesticide and reduced crop yields. Consider using a selective pesticide to minimize danger to beneficial predators and parasites.

Cooperative Extension Service publications have instructions for pest identification and optimum timing of pest control. Integrated pest management programs are available for many crops. Check with your cooperative extension agent to develop yours.

Near Kalispell, a good market for organic grains caused John Sheldon to switch 200 acres to organic farming. He says his biggest headache is weeds. But even with the extra fuel for tilling to subdue them, Sheldon estimates that not using chemical fertilizers or pesticides reduces his operating costs by 30 percent. He also relies on crop rotation to control weeds and increase the nutrient content of the soil. Sheldon says his yields for wheat and peas have been as good as if he were farming the land conventionally. Lentils didn't do so well because they have trouble competing with the weeds. With the expected higher price for organically grown food, he is hoping for an increased profit margin.

Hitting the Target

According to Jim Nelson, Extension Service weed specialist at Montana State University, millions of dollars are lost annually through wasted chemicals. Of 804 sprayers checked in clinics since 1983, 6 out of 10 were not properly calibrated. Based on the

average of 1,232 acres sprayed annually per sprayer, and a savings of at least $2 per acre in chemical costs, producers averaged a gain of $2,400 through accurate calibration.

Energy, time, and labor costs can be saved in several ways when applying crop chemicals through:

- Proper equipment
- Correct dosages
- Precise application
- Fewer trips over the field

Check out the spray rig. Are all the hoses and fittings snug and leak free? Rotate the booms and check the nozzles. The angle at which nozzles are mounted and the height of the boom above the ground influence the uniformity of application. After calibration, plugged nozzles are one of the biggest problems found in spray check programs in Montana. Throughout the season, clean nozzles frequently as well as the main strainer, and check for leaks in nozzles and for worn discs. Calibrate your sprayer output with your ground speed. One of your best investments could be to attend the "Operation Spray Check" program sponsored by your local cooperative extension agent.

Calibrate bulk chemical meters. Failing to calibrate meters to compensate for wear or differences in chemical viscosity (due to chemical type and temperature) can result in errors up to 26 percent.

Calibrate spray equipment. As ground speeds and nozzle types change, your sprayer's output will vary.

HINTS FOR METER CALIBRATION

When calibrating a meter, you have to maintain a flow rate above 4 gpm to get an accurate meter reading.

Meters are often calibrated at the manufacturing plant with solvents nearer the viscosity of water and gasoline than to most agricultural chemicals. Field check your new meter for accuracy.

Temperature changes in a typical season, or even in a typical day, can change the viscosity of a chemical enough to significantly alter metering accuracy. Try to calibrate at midday, or at temperature swings, to lessen the impact of the changing viscosities. (Regular calibration for viscosity will also catch changes due to meter wear.)

A clean meter is imperative for accuracy. This means flushing it after every use.

For chemicals with widely different viscosities, consider separate meters.

Although more expensive than a mini-bulk meter, a "legal for sale" meter (used by dealers) that automatically compensates for different viscosity fluids would probably pay for itself over time through savings in chemicals as well as time and labor.

You can measure using an induction cone in addition to, or in place of, a meter.

TIPS ON PESTICIDE SPRAYER NOZZLE ANGLES

Flood-tip nozzles need 100 percent overlap, or double coverage, to get a uniform spray pattern. Tilt the nozzle 45 degrees. Operate the flood nozzles under 30 psi, and space them no more than 60 inches apart. If your flood-tip nozzles are mounted to run less than 12 inches off the ground, space them less than 20 inches apart for good coverage.

Whirl-chamber nozzles require overlap. Tilting a whirl-chamber nozzle 15 degrees to 30 degrees improves coverage dramatically. Keep pressure below 20 psi.

Flat-fan nozzles require 60 percent overlap to get uniform coverage. This means that nozzles spaced 20 inches apart on the boom should spray a 32-inch swath on the ground. A 2- to 3-inch decrease in height can result in an unacceptable herbicide pattern.

Full-cone nozzles need approximately a 20 percent to 30 percent overlap for even application. These nozzles can be mounted perpendicular to the ground without affecting the spray pattern.

STEPS FOR CALIBRATING PESTICIDE SPRAYERS

Mounted sprayer. Fill the tank with water. Stake out an acre (43,560 square feet). Pick a comfortable driving speed--make sure to note the gear and throttle setting--and spray that acre. Then refill the tank, noting how much water it takes to fill it. If it's 20 gallons, this means that at the given ground speed the application rate is 20 gallons per acre.

Check the application rate on the chemical's label and mix the appropriate amounts of chemical and water to cover a specific amount of acreage.

Knapsack sprayers. Fill the sprayer with water and spray for 1 minute at a comfortable walking speed over the ground to be covered. (Constant ground speed and sprayer output are essential.) Measure the area sprayed.

Next, while standing still, use a bucket to catch the spray from the knapsack sprayer for 1 minute, then measure it.

Divide 1 acre by the area you covered.

Multiply the result by the amount of water applied to get the application rate in gallons per acre.

Divide the amount of chemical per acre called for on the label by your sprayer's application rate.

Add this amount to each gallon of water.

EXAMPLE:

1. You covered 220 feet in 1 minute and the spray swath was 5 feet wide. The total covered area is 220 x 5 or 1,100 square feet.
2. The amount in the bucket after 1 minute was 1/2 gallon.
3. 43,560 sq ft/1,100 sq ft = 39.6.
4. 39.6 x 0.5 gals = 19.8 gallons per acre (or 20 gallons in round numbers).
5. Say the chemical label calls for 32 ounces per acre. Divide 32 by 20. In this case you should add 1.16 ounces of chemical to each gallon of water in your sprayer.

Recalibrate any sprayer--knapsack or mounted--any time the ground speed or spray nozzle is changed. If the sprayer is used on different types of ground, such as flat grassland versus brush-covered hillside, or used by someone whose walking speed is different, the area covered will change. And different nozzles can increase or decrease the amount of solution sprayed.

OUT IN THE FIELD

Uniform application is essential. Best results are through smaller droplet size and more concentrated droplets. A slight breeze can bend pesticide sprays from air-blast systems, especially the high arc of the orchard sprayer, and air currents from ground speeds can cause extensive spray drift.

If possible, combine the fertilizing or pesticide operation with some other operation to reduce trips over the field. Sometimes crop chemicals can be applied together. (Be sure of compatibility before mixing any material together.) Applying fertilizers or pesticides through existing irrigation systems (known as chemigation) can be feasible.

Using an all-terrain vehicle to pull a separate sprayer unit uses less fuel and has less impact on the ground than a tractor.

Aircraft may be the most effective method for spraying noxious weeds in rough terrain.

CHAPTER 4

Looking at Livestock

In Montana, a large segment of the agricultural industry is range-fed cattle and sheep operations. Using pickups and trucks to distribute supplemental feed and check up on the animals consumes a good share of the energy budget in these operations. Ways you can save on fuel is found in an earlier chapter of this book titled "Squeezing Out the Last Drop."

Energy savings for five operations fundamental to all livestock operations are found in this chapter including:

- Harvesting forage
- Feed handling
- Watering
- Housing
- Manure handling

Browse through the latter part of this chapter for ideas on where energy savings can be made in specific livestock operations.

Harvesting Forage

In Montana, more acreage is devoted to forage production--hay, rangeland, pasture--than to any other crop. While considerable amounts of energy are used to irrigate and fertilize forage crops, harvesting operations usually top the list for energy consumption. Table 10 shows the approximate fuel usage for forage harvesting, hauling, and storage.

Here are some facts that may alert you to possible energy-saving areas.

MACHINERY

- Exceeding the rated PTO speed of the forage harvester can increase power used per ton chopped by 25 percent or more.

- Proper adjustment of the PTO clutch and belt tension saves power by eliminating slippage.

Table 10. Fuel Requirements for Forage Harvesting, Hauling, and Storage

Source: S.D. Parsons, Purdue University, Estimating Fuel Requirements for Field Operations.

Harvesting Method	Gasoline (gallons per acre)				Diesel (gallons per acre)			
	Harvesting	Hauling 1st mile	Hauling add'l mile	Blowing	Harvesting	Hauling 1st mile	Hauling add'l mile	Blowing
Hay, conv. bales	0.75	0.20	0.15		0.54	0.14	0.11	
Hay, round bales	0.65	0.40	0.30		0.45	0.29	0.22	
Green chop	1.35	0.55	0.20	0.50	0.95	0.35	0.14	0.35
Haylage	1.80	0.30	0.30	0.35	1.25	0.20	0.20	0.25
Corn silage	5.20	2.00	1.30	2.00	3.60	1.40	0.90	1.40
Ear corn	1.61	0.40	0.24		1.16	0.29	0.17	
Shelled corn	2.25	0.25	0.15		1.62	0.18	0.11	
Small grains	1.50	0.12	0.07		1.08	1.08	0.05	

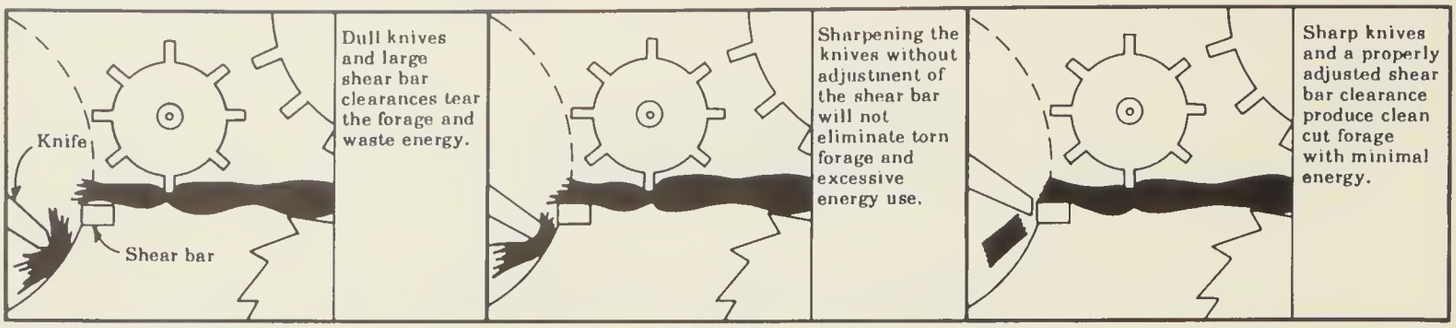

Knife
Shear bar
Dull knives and large shear bar clearances tear the forage and waste energy.
Sharpening the knives without adjustment of the shear bar will not eliminate torn forage and excessive energy use.
Sharp knives and a properly adjusted shear bar clearance produce clean cut forage with minimal energy.

Figure 25. Forage Chopper Adjustments. (Reprinted from Reducing Forage Harvest Energy Cost, Northeast Agricultural Engineering Service)

- Chopper knives dulled by even 1/64-inch demand about twice as much power as sharp knives.
- For knife-to-shear bar setting, the minimum clearance specified in the owners manual is best (see figure 25).
- A recutter screen in a chopper can require 10 to 20 percent more fuel per ton of silage.
- Proper adjustment of silo blower blade tip clearance is about 0.06 inch, or so a dime on edge can slide between blade tip and shear plate, but not a nickel.
- Exceeding the rated PTO speed for blowers wastes power.
- Long engine idling periods and hauling partial loads are the largest energy wasters in hay hauling.

CHANGING METHODS

- In a flywheel harvester, changing the feed ratio to get a specific length of cut at a slower speed (rather than removing knives to get the same cut at a higher speed) will save energy.
- Using by-product feeds conserves other feeds that require more energy to produce. Some by-product feeds are:
  - distiller's grain
  - cobs
  - stalks
  - beet tops
- Feeding from fence line bunks saves time, keeps the tractor on a good surface reducing draft, and minimizes gate opening and closing.

Cattle in the R. J. Feedlot at Dillon are munching on distillers wet grains and spent beer from the alcohol distillery next door. The spent beer (known as stillage) is given free choice, while the distillers wet grains are mixed with steam flaked barley, hay, and straw. Ron Johnson, owner of the feedlot and distillery, says the feed produces significant weight gain in the cattle without the aid of antibiotics, hormones, or digestive stimulants.

Fababeans--both bean and forage--are good livestock feed. According to Jim Sims, Professor of Soils Science at Montana State University, Montana ranchers could save money (and the energy required to transport soybeans into Montana) by feeding fababeans mixed one to one with barley instead of soybeans. In dryland cropping, the Montana grower should get around 1,000 to 1200 pounds of fababeans per acre. Under irrigation, fababean yields rival those of silage corn, and without the nitrogen requirement.

Feed Handling

Grinding, rolling, flaking, and mixing feed ingredients into a complete ration are basic to livestock production. Perhaps these tips will cut your power requirements.

- How long has it been since you looked at the manufacturers' operating recommendations on grinders, mixers, and other feeding equipment? You may find some cost-saving tips there.

- Review the "Around the Farmstead" chapter for tips on maintaining electric motors for efficiency.

- Grind **dry** feed material without overprocessing it. It takes more energy to grind moist grain than dry grain, and many animals can digest coarsely prepared feed. As a comparison, figure 26 shows the energy needed to grind corn at various moisture contents, and with differing screens that control the size of the end product.

- Up to one-half of feed processing energy costs can be saved by using proper screen sizes and maintaining equipment. Grains, particularly corn cobs, can be very abrasive on even the hardest of cold cast irons. Dry or worn bearings and poorly adjusted belt drives use more energy.

- Rather than grinding, perhaps another method of processing feed is best. Dry shelled corn can be just as efficient a feed for beef cattle as ground shelled corn. Feeding free choice when possible saves on costs for mixing feeds.

- Emptying conveyors before stopping motors reduces load and energy requirement when restarting.

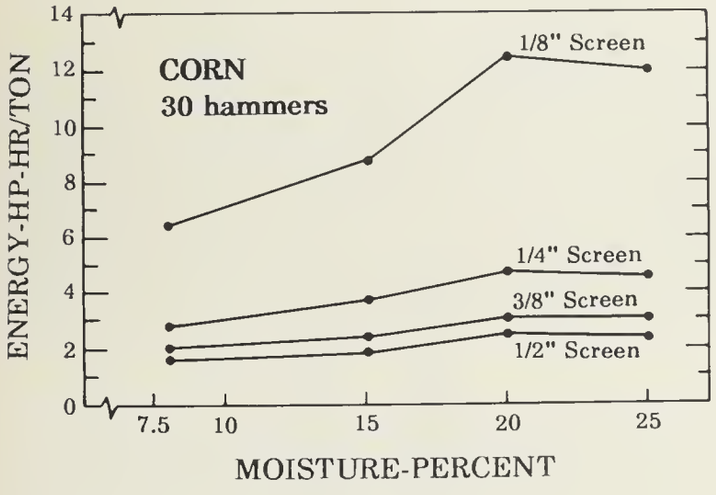


Figure 26. Energy Required to Grind Corn. Corn with moisture content of 8, 15, 20, and 25 percent was ground on a mill with 30 hammers, with screens ranging from 1/8-inch to 1/2-inch. Up to 20 percent moisture content, the energy required for grinding increased with the increase in moisture content. As screen opening increased, the energy required per ton decreased. (Adapted from Fuels for Agriculture, Wyoming Energy Conservation Office; Data source: USDA)

When purchasing equipment, consider the materials to be handled and the power requirements of different systems. Reduced operating costs over the life of the equipment can more than compensate for a higher purchase price.

- Evaluate the difference in power requirements between an electrically-powered mill and a tractor-powered mill. Electricity may be less costly and more plentiful than diesel fuel.

- Although roller mills are more expensive than hammermills, their operating costs are lower.

- Low horsepower grinders need more time to do the job, but use minimal energy.

- Conveyors or augers can replace vehicles in distributing feed. But remember, the capacity per horsepower of a conveyor is usually much greater than an auger.

Savings at the Watering Hole

Heating stock water can add significantly to electricity bills. See if some of the following tips will save you money.

- Keep stock water at the minimum temperature above freezing that will encourage drinking (usually around 40 degrees F). Check water temperature with a thermometer until the proper setting is achieved. Thermostats on heating units are not precision instruments and can keep water at higher temperatures than necessary. Unplug them when they aren't needed, rather than relying on the thermostat for shutoff.

- Thermally sensitive valves that require no power source can be installed to circulate water in the tank when the temperature nears freezing.
- Painting the exterior of the tank a dark color will help absorb solar heat.
- A well-insulated tank can substantially reduce the energy needed, and a stock tank cover such as floating styrofoam reduces heat losses.
- Solar heated stock tanks can eliminate the need for supplemental heating.
- A stock tank that uses heat from the soil like that in figure 27 can minimize the amount of electricity necessary to heat the water.

Other energy saving methods for stock watering might be installing units that let the animal control the water supply. Nipples in hog waterers and push floats in horse waterers are two examples.

Solar-powered stock waterers can be feasible in remote areas where the cost of installing electric lines would be prohibitive.

Gravity-flow stock waterers have expanded rangeland use and have saved pumping costs for many ranchers.

Even waterwheels can be used to power pumps.

INSULATED STOCK WATERING TANK

Enclose the water line in a 12-inch culvert, or similar size enclosure. Extend this structure from at least three feet below the frost line up to the surface.

Insulate the enclosure from the frost line up, between the tank and a concrete foundation, and the tank.

Install a valve with a drain so the water can be turned off and the unit drained when not needed.

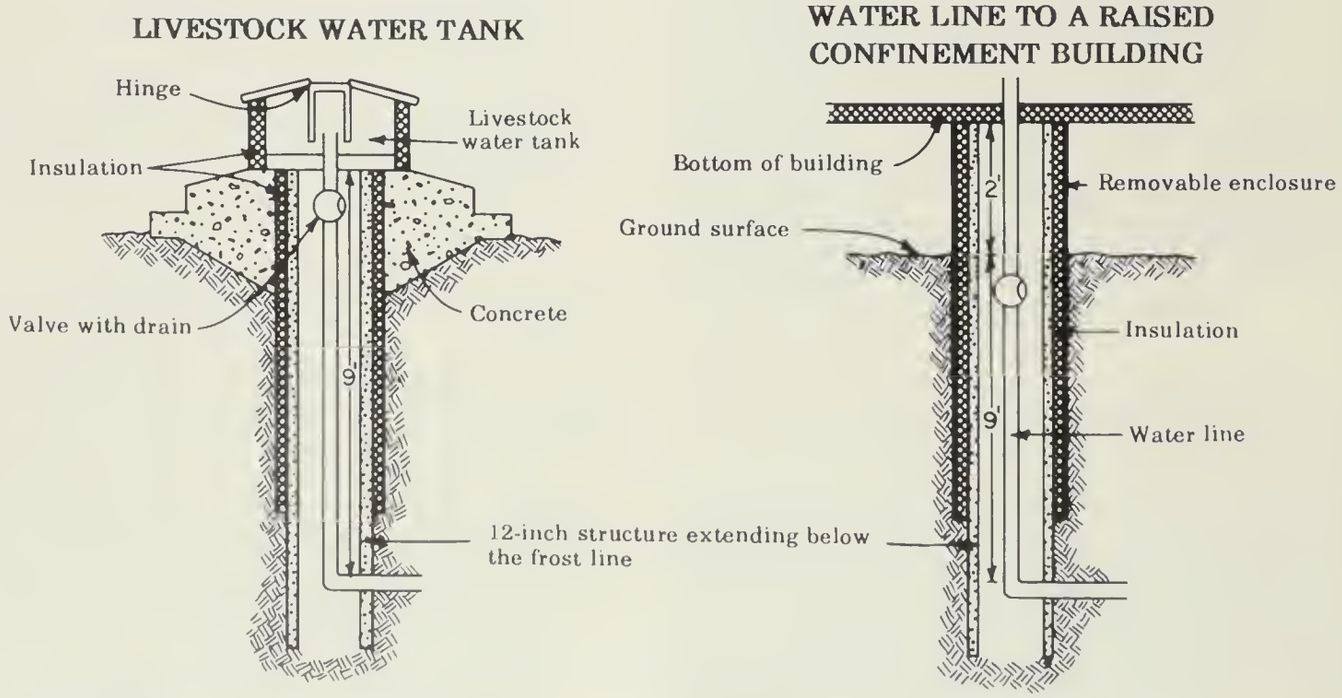
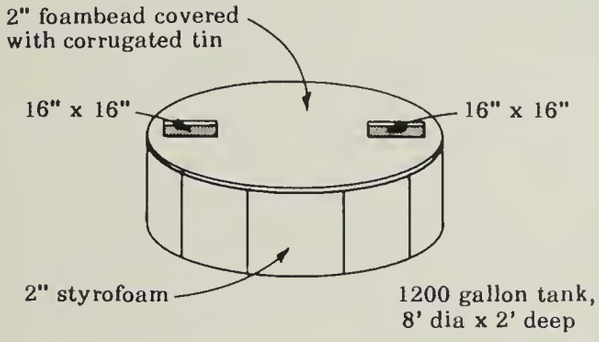


Figure 27. Insulated Stock Tank. (Reprinted from Fuels for Agriculture, Wyoming Energy Conservation Office)

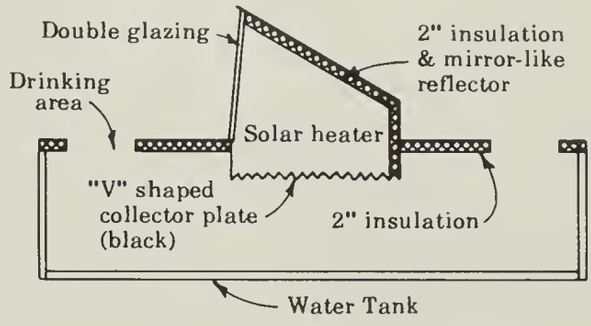
During the 1985-1986 winter, a DNRC-funded project enabled George Austin of Glasgow to determine the feasibility and advantages of insulated and solar-heated stock tanks. He found that an insulated stock tank with a lot of use stayed almost free of ice, forming a crust only on a few of the coldest days. The insulation retained the warmth of the water, and constant use by the cattle kept the tank replenished with 40-degree water. A heater was no longer needed.

In more remote areas, Austin installed solar collector units on stock tanks. They stayed free of ice even with the temperature down to -25 degrees F. and a wind chill factor of -60 degrees F. Austin figures he saved 300 gallons of gasoline since he could check the solar-heated tanks twice a month instead of daily.

The project summary and stock tank plans are available by writing DNRC.



Insulated stock tanks retain the warmth of the water.



Solar collector units keep stock tanks free of ice in -25 degree weather.

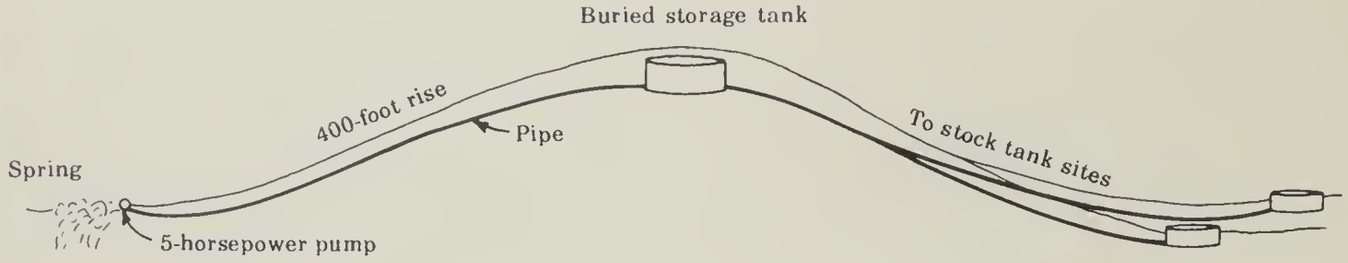
On Ed Wilcox's ranch near Rapelje, solar power saves cattle a 1-1/2 mile walk to water. Panels of photovoltaic cells convert sunlight to electricity to drive a positive displacement pump. The pump lifts water from a 50-foot well at 8 gallons per minute and delivers it through 8,000 feet of pipe to the stock watering tanks. Batteries store the current from the solar panels for use on cloudy days. During the winter, Wilcox directs the water into another piping arrangement which takes water to troughs at his ranch. Because he was over 2 miles from power lines, the solar panels were cheaper than bringing in electricity.

Mike Carlson, Dawson County District Conservationist, says a photovoltaic system has been working dependably since 1982 on the Don Miller ranch near Glendive. The solar panels provide the power to pump water from a well to a large capacity stock tank. The system has helped livestock distribution in a remote pasture that previously had a poor water supply. Photovoltaic panels have also been converting sunlight to electricity for stock water pumps on the Don Shaules ranch near Ballantine.

Replacing a ditch with a combination pump-gravity flow stock watering system has paid off in large fuel and maintenance savings for the Hagenbarth Livestock Company. Dave Hagenbarth says it has also let them make much better use of the 18,000 acres of mostly winter rangeland near Dillon.

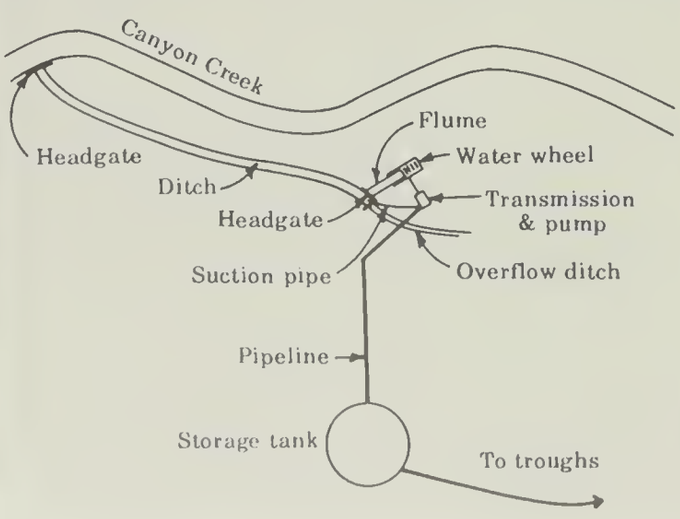
Lifting water from a warm spring up a 400-foot rise gives plenty of pressure to gravity-feed the water to 11 troughs through 14 miles of buried pipeline. Hagenbarth says they'll add another 6 troughs eventually. They pump from the spring year around, and have found that by pumping continuously they don't need propane or electric pump or tank heaters in the winter.

Although the small 5-horsepower pump draws electricity, Hagenbarth says it's minimal compared to the fuel used previously for maintaining the ditch with tractors and cats.



After becoming frustrated with electrical and diesel pumping plants breaking down, the members of the Vipond Park Stock Association installed a water wheel and gravity flow system to bring water to their stock on rangeland near Melrose. Rich Franko says it's serving them well and they don't have any charges for electricity or diesel.

A headgate on a stream directs water into a 300-yard ditch that flows into a flume. The flume feeds the 30 buckets mounted on the 4-foot wide by 8-foot diameter water wheel. A driveline-transmission-belt configuration runs a 3-piston pump. The pump lifts water 726 feet from the creek through a 1,800-foot 1 1/2-inch pipeline to a 23,000-gallon storage tank. From the storage tank water runs down through a network of about 2 1/2 miles of pipeline to fill 6 stock tank sites.

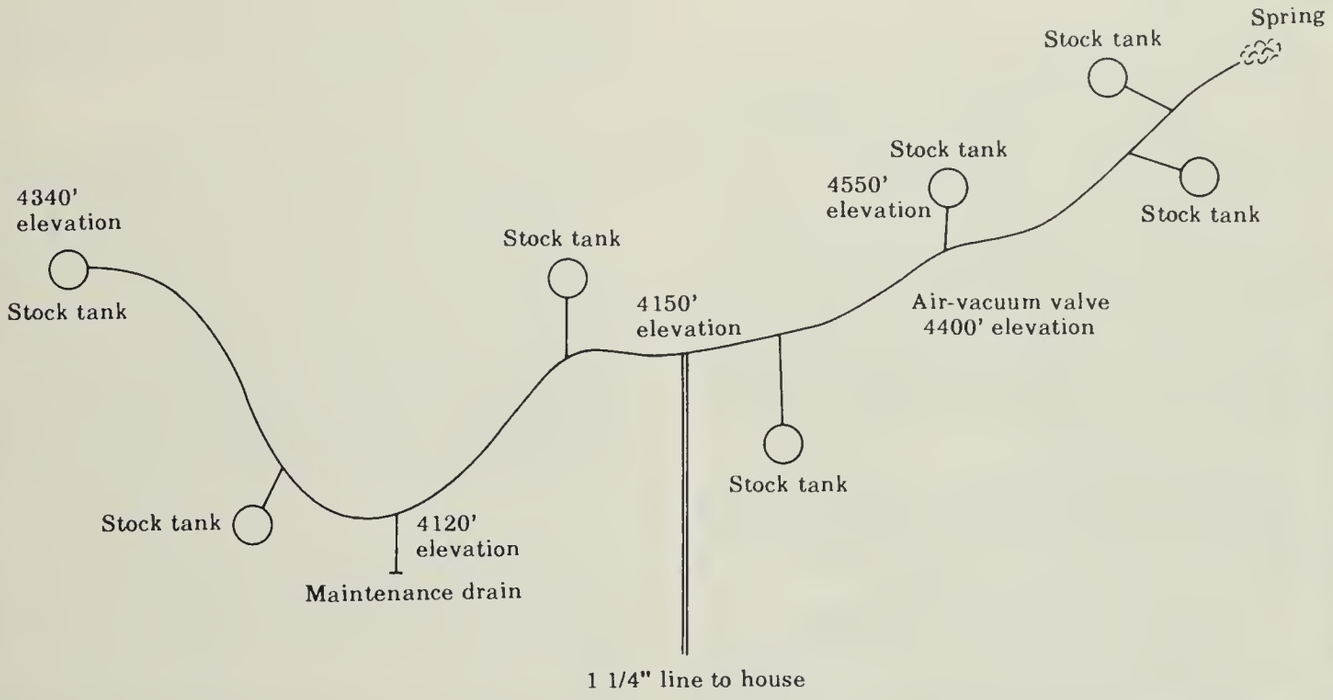


An energy-efficient water wheel provides the power to deliver water to cattle of the Vipond Stock Association.

Cattle overgrazing near natural water sources while other rangeland stood empty, caused Ken Maki to look for better watering methods on his ranch near Belt. With the help of Cascade County Soil Conservation Service, he figured a 30-gpm spring on top of a hill would give him enough volume and pressure to distribute water to "dry" pasture hill tops eliminating the need for an expensive pump and associated power costs. The gravity-feed system Maki developed not only waters his cattle, but serves his home as well.

From the spring, a 2 mile, buried 1 1/2-inch pipeline drops 475 feet to the bottom of a coulee, then elevates another 150 feet carrying water to 7 hilltop troughs. A vacuum pressure relief valve midway in the pipeline prevents the formation of air pockets. Flow control valves at the stock tanks at lower elevations prevent excess flow at low points.

After determining there was sufficient water supply, Maki tapped the 1 1/2-inch line with a 1 1/4-inch pipeline to the ranch home. This installation eliminated the need for an electric water pump while supplying good quality water with excellent pressure.



The summer grazing range near Dillon of the Bannack Grazing Association has been supplied with water from a gravity-flow system for the last 10 years. Dennis McCoy, manager, says the system, engineered by the Soil Conservation Service, has been virtually maintenance free, and never needs priming. They water around 800 cow-calf pairs on 13 sections.

Running from a developed spring around 6400 feet elevation, the buried pipe drops to about 6200 feet, then travels up and down hills and gullies, climbing almost as high as the starting point a couple of times. The flow is a steady 8 gallons a minute through the 12-mile system, until the lower end where it drops to 6 gallons. Initially the pipe is 1-1/2 inches, later reducing to 1-1/4 inches. Vacuum breakers keep air locks from forming in the pipe. Valves in all low spots of the pipe let the system be easily drained for winter.

In previous years, the cow herd was split, but now it's combined under an intensive grazing system. Dennis says the size of the watering tanks need to be larger for the larger herd size, and cautions anyone putting in a gravity feed system to plan water storage for the maximum number of head.

Housing

In most beef cattle or sheep operations, little or no mechanical ventilation or supplemental heat is required. If you're considering warm barns you may find that gains do not offset the added cost of the insulation, or heat, particularly when the power for ventilation is considered. Ventilation fans usually aren't necessary in cold barns.

Both heating and ventilation are usually top priority items in swine production facilities, and a must in poultry facilities.

VENTILATION

When warm animal structures are necessary, consider the use of a convertible system--closed, warm, and mechanically ventilated in cold months and naturally ventilated in warm months.

In heated buildings, temperature-controlled fans, variable-speed fans, 2-speed fans, or motor-operated fan shutters can decrease fuel requirements by reducing outside air intake. But too little air flow leads to increased carbon dioxide, higher temperatures, and moisture--a breeding ground for diseases and physical stress.

Turning off fans in warm weather when the livestock are out of the building saves energy and prevents drawing warm air into the barn.

Cleaning off dust and oil that builds up on the fan blades and louvers will save 5 to 10 percent on energy in winter months, and help fans move more air in the summer months. Lubricate louver hinges with graphite powder rather than oil to minimize dust collection.

Fans with high cubic feet per minute (cfm) for their watt ratings will move the maximum amount of air for each unit of electricity used.

If variable speed fans ventilate your buildings, a motor controlled by a straight resistance unit wastes energy at low speed, and can damage some types of motors.

SPACE HEATING

Insulating the walls, ceiling, roof, under the floor or around the foundation minimizes heat loss in the winter and heat gain in the summer. Weatherstripping around doors and windows and plastic film fitted tightly over windows will reduce infiltration heat losses and simultaneously provide a storm window effect by cutting conduction losses.

Instead of heating the whole room consider using electric radiant heaters to warm small areas, or use infrared lamps for spot heat in semi-open structures such as milking parlors.

Balance the inside temperature against ventilation requirements. In enclosed, well-insulated confinement buildings, it may be more economical to increase the heating load to hold down the ventilating requirements. Cooler air holds less moisture than warm air. Therefore, a lower setpoint temperature can result in more condensation and require higher ventilation rates.

Turning off the whole heating system, pilot light included, will save energy in the summer.

Accurate, dependable thermostats on all heating units are a must for energy efficiency. Coil sensors are generally more reliable than mercury bulbs. Mercury thermostats accumulate dust on the bulb and spring, which greatly increases the on-off range. Installing dust protectors or taping the openings aren't recommended since they tend to "insulate" the thermostat against the room temperature changes.

Proper maintenance can reduce your fuel bill as much as 10 percent. Check furnace filters every two months during the heating season; clean or replace as needed. Clean fan blades annually. Keep air vents free of dust, lint and litter. You might want to have your heating equipment serviced by a reputable heating specialist before the start of each heating season.

Managing Manure

Manure has to be disposed of and capturing the energy within it can recoup some of your handling costs.

On the average, a cow produces 20 tons of manure a year. From this bulk, 0.5 percent is available as nitrogen, 0.25 percent as Phosphate (P_2O_5), and 0.6 percent as Potash (K_2O_5). Storing the manure rather than spreading it daily protects these nutrients. Table 11 shows the number of pounds of nitrogen, phosphate, and potash produced

Table 11. Manure Nutrient Loss (Cow/Year) by Various Manure Handling Systems

Element	Lbs Produced*	Daily Spreading			Piling, Spreading, and Soil Compaction			Tight Storage–Spread and Soil Incorporated		
		Lbs Lost	Btu Lost	Gal Gas Equiv. Lost	Lbs Lost	Btu Lost	Gal Gas Equiv. Lost	Lbs Lost	Btu Lost	Gal Gas Equiv. Lost
Nitrogen(N)	200	120	3,000,000	24.4	40	1,000,000	8.13	40	1,000,000	8.13
Phosphate (P_2O_5)	100	20	80,000	0.65	0	0	0	0	0	0
Potash (K_2O)	240	120	240,000	1.95	48	96,000	0.78	0	0	0
Energy Loss (per cow/year)		3,320,0000 Btu 27 gallons gas			1,096,000 Btu 8.9 gallons gas			1,000,000 Btu 8.13 gallons gas		
Nutrient Losses Assumed		60% N; 20% P_2O_5; 50% K_2O			20% N; 0% P_2O_5; 20% K_2O					

*Assumes one cow produces 20 tons manure/year (0.5% N; 0.25% P_2O_5; 0.6% K_2O). Source: Cooperative Extension Service, University of Vermont, The Dairy Farm Energy Book.

by a cow per year and compares the nutrient losses from three manure handling systems. The gallons of gasoline represent the energy it takes to manufacture these nutrients in commercial fertilizers. Losses vary with rainfall, wind, snow cover, and other factors.

Storing and then spreading the manure not only retains nutrients, it also saves the cost of fuel and wear on your tractor that would occur in daily spreading (especially in winter when you have to heat the engine before using it). Timing manure spreading to avoid deep snow or mud saves drag on tractor.

Lagoon flush systems in poultry facilities can minimize handling and fly problems.

Your Cooperative Extension Service has bulletins to help you effectively manage manure disposal.

The Beef Herd

A cow-calf operation is one of the most energy-efficient methods for converting forage that we humans can't use into a product we can. The largest energy expenditure for a cow-calf operation is for the fuel used in checking cattle and hauling salt and feed to grazing cattle. Anything that can be done to reduce the number of trips will save fuel.

Rotational grazing also saves energy. Cattle are concentrated in small areas, reducing the time and fuel required to check and distribute supplemental feed.

Check cattle with a motorcycle, ATV, or horse instead of a pickup.

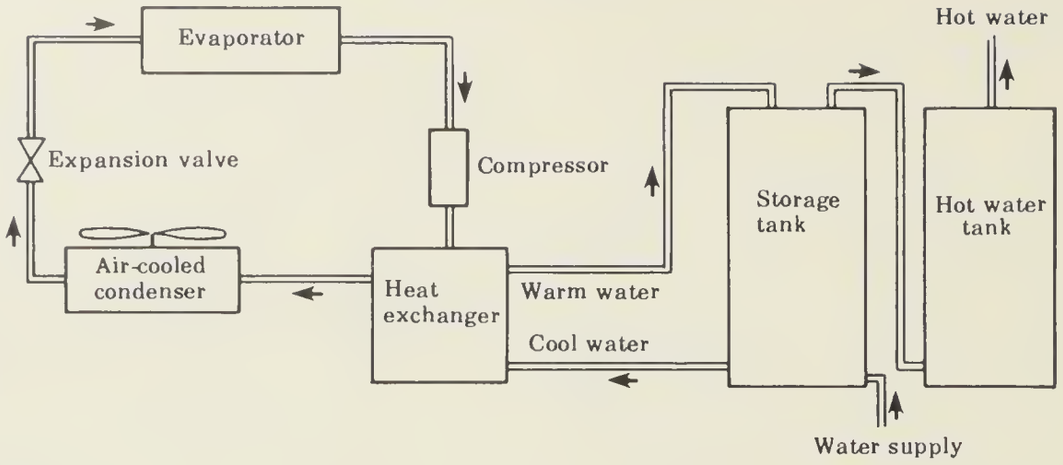
At the Dairy

Water heating and milk cooling can use 40 to 50 percent of the electrical energy required in a dairy operation. Here are some ideas to save on water heating bills.

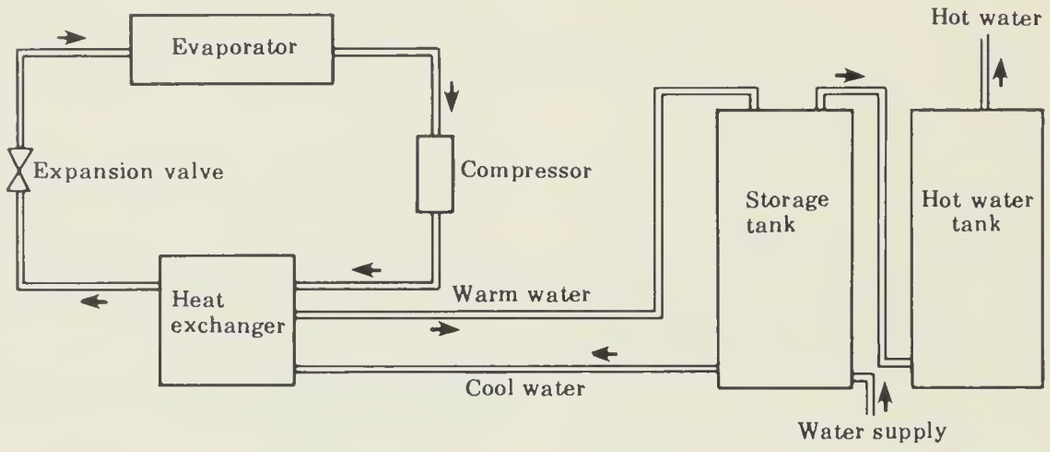
- Check your faucets. A faucet dripping once per second will waste 4 or more gallons of hot water a day. Spring-operated shutoffs on heavily used faucets can prevent the loss of many gallons of hot water every day.

- Minimize hot water use. Every time hot water is used, heat is lost in the distribution pipes. A water heater close to where you use hot water minimizes heat loss in distribution pipes, and

a. Add-on heat exchanger retains present air-cooled condenser



b. Complete condensing heat exchanger eliminates air-cooled condenser



c. Complete condensing heat exchanger producing two different water temperatures

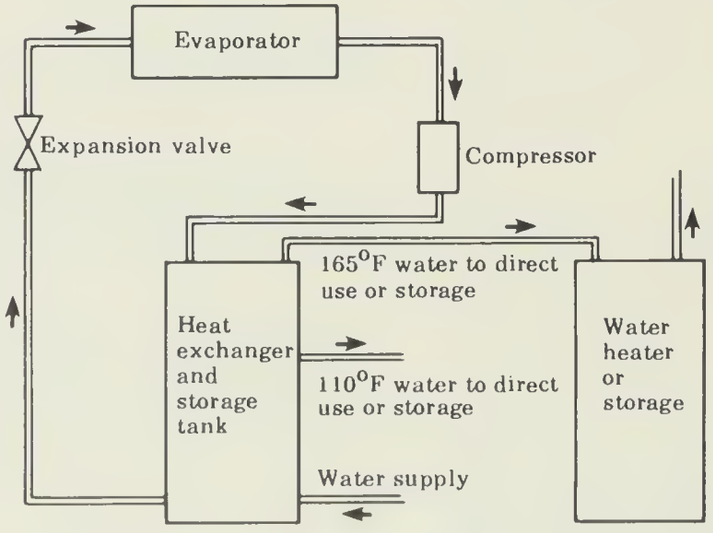


Figure 28. Types of Heat Exchangers. (Reprinted from Dairy Farm Heat Exchangers for Heating Water, Northeast Regional Agricultural Engineering Service)

the amount of pipe to insulate. Use cold water for platform and floor cleaning when possible.

- Don't overheat the water--160 degrees F is the maximum needed for cleaning equipment.

- Insulate hot water distribution lines with at least 3/4-inch of pipe insulation, and the hot water heater with 3 1/2-inches of blanket insulation. DNRC has booklets that show you step-by-step how to insulate an electric or gas water heater.

- Drain water from the bottom of a hot water heater monthly. This keeps mineral formations from interfering with the transfer of heat to water, and can save 15 to 25 percent of water heating costs. Flushing hot water heaters every six months cleans out any accumulated solids.

- Prevent waterlogging in the water holding tank of the pressure system. If the pump starts and stops more than once every two minutes, it uses more power and can damage the motor.

- A maladjusted float in the pipeline rinse tank can waste 5 to 10 gallons of hot water per day.

Check these maintenance procedures on milking equipment for energy savings.

- Maintain vacuum pumps, milk coolers, electric fans, and other equipment for top performance.

- Adequately ventilate the compressor head--keep it out of the sun, in a cool location, and at least 18 inches from walls. Clean condenser coils periodically (especially in the summer) with a stiff brush and pressurized air or a vacuum cleaner. Clean screens covering air vents. Dirty fins and poor air movement restrict heat transfer, causing a 10 to 20 degree F rise in surrounding air temperature. Each rise of 10 degrees F causes about a 10 percent increase in electrical consumption.

- Locate your milk cooler compressor so it exhausts heat indoors during winter and outdoors during warm weather.

- Install a heat exchanger (diagrammed in figure 28) to recover the heat from the milk cooling system. It should be possible to recoup a one-time capital investment for the heat exchanger unit, a hot water storage tank, and some plumbing in about three years.

Heat from the hot refrigerant circulating through the compressor can provide most of the heat for the water needed to wash the equipment. Bulk cooler performance is often improved because heat transfer to the water is better than transfer to air.

An inexpensive "breadbox" solar water heater can be used to pre-heat dairy wash water during the summer. It is made from a salvaged water heater, painted black and placed in an insulated box with a fiberglass covering as illustrated in figure 29. Heat absorbed from the sun raises the temperature of the water which is piped off the top to the cold inlet of the water heater. Well pressure provides sufficient water flow so that pumps or controls aren't necessary.

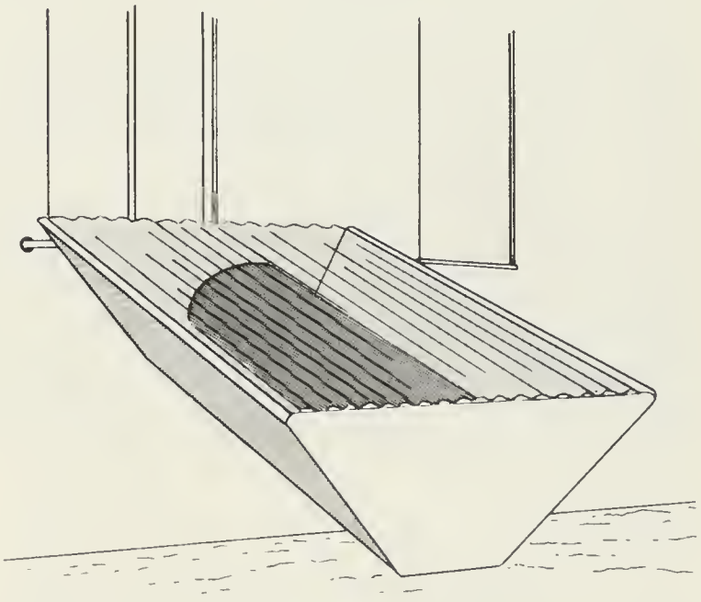


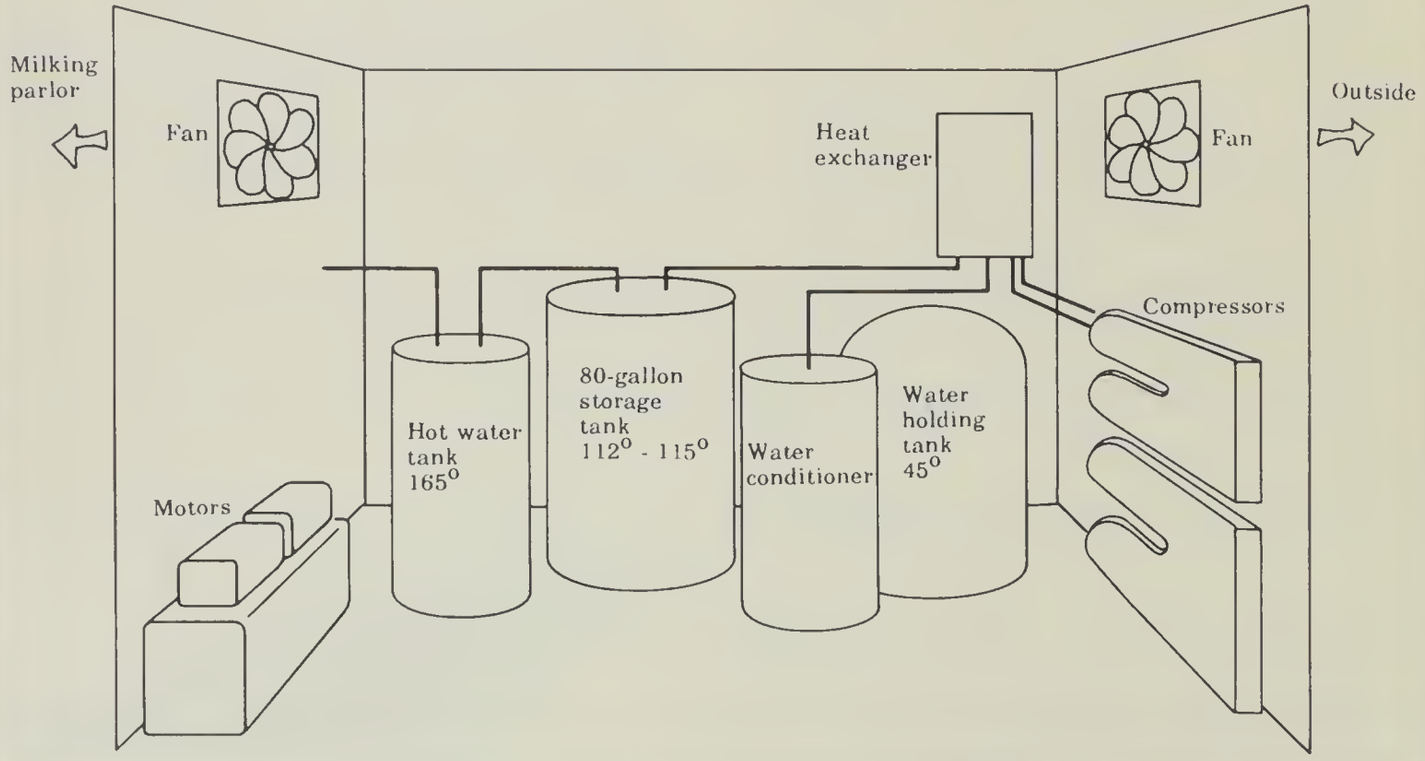
Figure 29. An inexpensive "breadbox" solar water heater. (Adapted from Small Farm Energy Primer, Small Farm Energy Project)

Milo Todd, who runs an 80-cow dairy near Bozeman, takes advantage of every energy-saving method he can. During the winter he pulls heat from his engine room into his milking parlor. The exhaust heat from two milk cooling compressor motors, an air compressor, and a 9-horsepower vacuum pump motor warms his parlor so that he doesn't need auxiliary heat until the outside temperature drops below minus 20 degrees F. In the summer he exhausts that heat outside.

A heat exchanger takes the heat from his milk cooling process to warm incoming water from 45 degrees F. to 115 degrees F. He stores this preheated water in an 80-gallon insulated tank. From there it's piped to a second water heater and heated to 165 degrees for equipment cleaning.

His savings extend to forage production. He is able to get two crops from his oats. A first cutting at the boot stage makes 8 to 10 tons of silage per acre. The stubble left comes back in the fall and he is able to harvest up to 90 bushels of grain per acre.

Instead of manufactured fertilizers he uses the manure from his cows on his home fields. Todd says his cows eat less feed and produce more milk from the organically grown forage and grain than they do from the feed from his rented land, on which he has to use commercial fertilizers.



On Swine

Swine buildings frequently are dusty, especially under minimum ventilation during the colder months. Clean the air filters and louvers daily if necessary to minimize the resistance to air movement.

Automatic controls in farrowing houses that slowly adjust electric heating units as the temperature increases or decreases inside the building are great energy savers. They also avoid the rapid temperature changes that can occur if the operator only has the alternative of turning heating units completely on or off.

The proper environment is provided most efficiently when all pens, crates, or other holding areas are fully stocked with animals. It costs no more to operate a heat lamp for a litter of ten pigs than it does for a litter of six.

Try to separate different age groups of pigs by room or building. If two age groups of pigs occupy a

single nursery room, the temperature must be maintained high enough for the younger pigs. This additional heat is wasted on the older pigs since they have lower heat requirements.

If two different age groups must occupy a single room or building, place the older or larger pigs across the aisle from the younger or smaller pigs. The even distribution of body heat from all the pigs will create the same heating or ventilation demands at all points in the length of the building. This arrangement is preferred because it is virtually impossible to provide two distinctly different environments in one room with any degree of energy efficiency.

On Sheep

Sheep are gathered, handled, and treated several times yearly, for worming, shearing, vaccinating, feet trimming, and sorting and marketing. Typically a pickup or tractor is driven out to the fields to slowly herd the animals back, with much idling at pasture gates. With forethought, some of these management procedures can be combined so that a flock could be herded together only three or four times yearly, instead of twice as often. This would save energy without endangering the well-being of the sheep.

A good working dog can be sent a quarter of a mile or more to gather and bring a flock of sheep to the flock owner. This seemingly small daily saving of gasoline adds up over time.

Energy-saving marketing methods include package shipments and buying and selling over the phone. In one method the sheep rancher sells replacement ewes directly to several buyers in an area. The ewes are delivered in semi-trucks to a central point close to the individual buyers who come to pick up their purchases. Another marketing method pools lambs from several local producers for a buyer. Each rancher brings his lambs a short distance to a central pickup point for loading into a semi-truck, which delivers them to the buyer.

Poultry Facilities

Brooding accounts for about 71 percent of the energy used in on-farm poultry production. Lighting and ventilation use 7 and 4 percent, respectively. Waste handling, and operation of feeding and egg collection equipment are responsible for about 18 percent.

Solid brooder guards hold in more heat. You might be able to turn off pilot lights on every second brooder in warm weather and during the latter stage of brooding.

Inspect your mechanical feeders to eliminate feed leakage and waste, which increases feeder running time and electrical consumption in addition to increasing feed costs. Check fans and louvers weekly to keep them free of dust and feathers.

Continual flow watering systems increase water and energy requirements over other systems. Check periodically to minimize water leaks. Intermittent watering programs can reduce water and energy requirements, but require more close supervision to prevent malfunctions.

Computer control of the poultry house environment promises to reduce labor and energy costs. Every 5 to 10 minutes a computer samples inside and outside temperatures and adjusts the heating, lighting, and ventilation.

Energy-efficient ventilation and cooling of poultry houses can be complex. Obtain assistance from the Cooperative Extension Service or agricultural engineers.

Beehives

Solar hives for wintering honey bees can help colonies survive Montana winters with less loss. USDA Agricultural Research Service scientists have designed a new translucent hive cover that lets the sun warm the hive. The covers are made from white sheet plastic and are relatively inexpensive. Wintering bees typically form tight clusters and sometimes starve as they fail to move from empty frames to honey-filled frames in a hive. In the plastic-covered hives in midwinter ARS scientists found bees almost uniformly distributed.

CHAPTER 5

Around the Farmstead

In the Home

Take a close look at your home, and other residences on your property. They can be using as much or more fuel and electricity than your farming operation. Caulking, weatherstripping, and insulating can stop many of the leaks. So can turning down your furnace, insulating your water heater, and installing water savers. Simply changing your energy habits around the house can make quite a difference in your energy bills. For ways on how to save, write for the catalog of free energy books from DNRC.

In western Montana, residents in the Bonneville Power Administration's service area can have a free energy audit on their home. In other Montana areas, your local utility may also offer free energy audits. Call them to schedule yours.

Landscaping for Protection

Winter. Well-located trees and shrubs can cut your winter fuel consumption by 10 to 30 percent. Planted close to buildings, shrubs not only reduce wind currents that otherwise would chill the outside surfaces, but can create a "dead air" space that slows the escape of heat from a building. Windbreaks can be located to control snow, too, reducing the energy required to remove snow from around homes, other buildings, and roads.

Summer. Shading from trees and shrubs controls solar radiation in the summer. One study showed that a temperature difference of 8 degrees between shaded and unshaded wall surfaces was equivalent to a 30 percent increase in insulating value for the shaded wall. And, the dead air space created by the foundation plantings helps insulate your home from hot outside air, reducing the need for air conditioning.

Using native grasses, shrubs, and trees in landscaping conserves water and the energy to pump it.

You can get help for planning windbreaks (types of trees, length of rows, location, etc.) in your area from the Soil Conservation Office. Young trees are available for spring planting at reduced rates through the county agricultural extension service. Also, the Agricultural Stabilization and Conservation Service may be able to offer cost sharing assistance through its Agricultural Conservation Program.

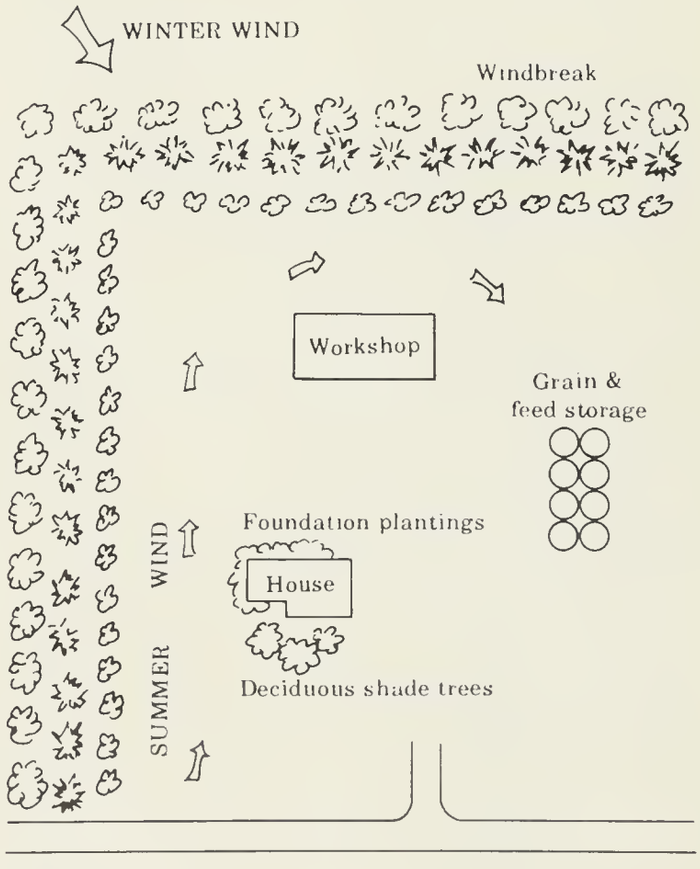


Figure 30. Energy-Saving Landscaping.

Lighting Facts

Although few farms are overlighted and lighting is a small part of the energy bill, you can still save energy with minimal effort. Many of the facts seem obvious, but surprisingly, their value is often overlooked.

Well-placed windows make it possible to use daylight for doing much of your general inside work.

Light-colored walls, ceilings, and floors reflect more light to work areas. For instance, white will reflect approximately 80 to 85 percent of the light, tan 30 to 50 percent, sky blue 35 to 40 percent, and cardinal red 20 to 25 percent.

Clean bulbs and reflectors mean better light, often with a lower intensity bulb. A clean 25-watt bulb with a clean reflector has the same light intensity as a clean 40-watt bulb with no reflector or a dirty 60-watt bulb with no reflector. Figure 31 shows how reflectors help put light where you want it.

An inefficient ballast can be costing more in power than the light itself. While a ballast will draw wattage from 5 percent up to the rated wattage of the bulb, it shouldn't take more than the total wattage of the bulb.

There is no easy way to detect an inefficient ballast short of an energy audit by your local power company. But be aware that as ballasts age, their efficiency deteriorates, and some ballasts will be more efficient than others.

Ballast life is directly dependent on ballast temperature. When purchasing new fixtures or replacement ballasts, check with your lighting vendor to get the most efficient ballast for your lighting task.

In a recent rural energy audit done by Park Electric Cooperative of Livingston, the auditor found a 175-watt mercury vapor yard light drawing 800 watts due to a poor, inexpensive ballast. The light was only 2 years old.

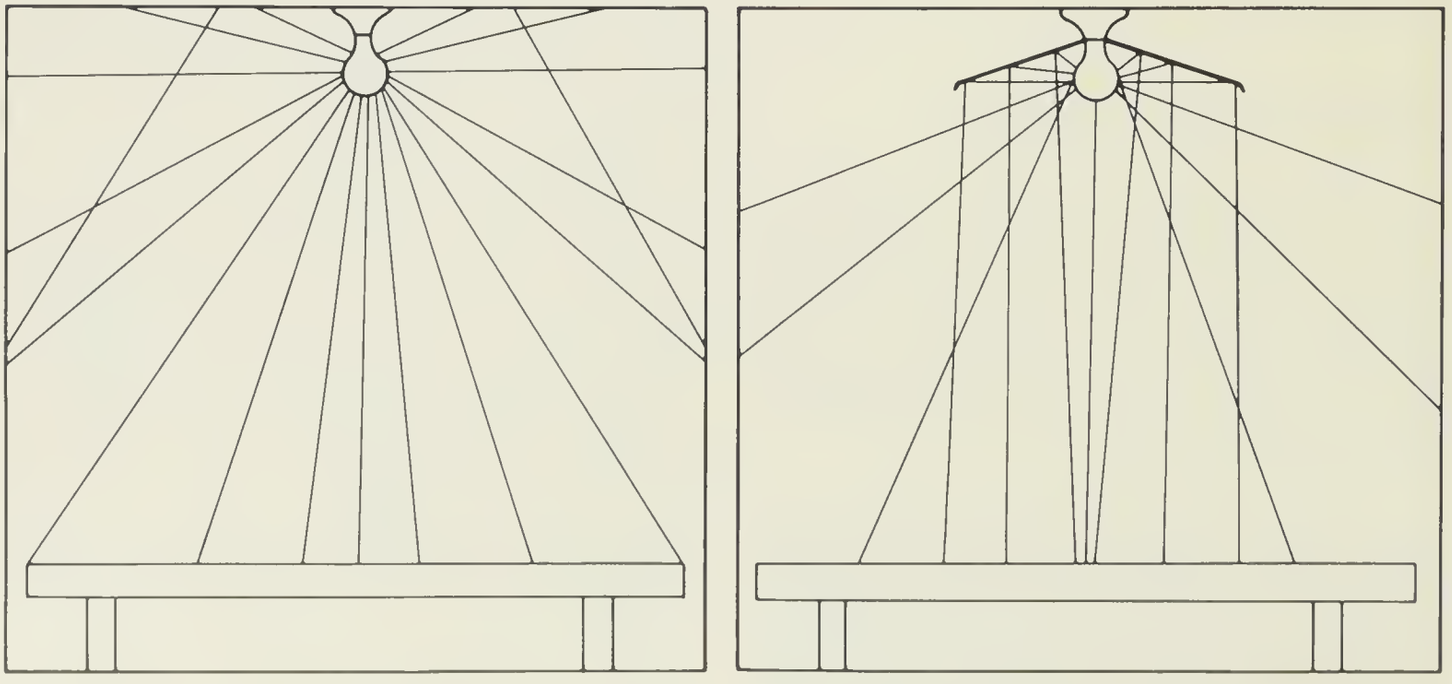


Figure 31. Reflectors Direct Light. (Reprinted from Efficient Lighting for Farms, Northeast Regional Agricultural Engineering Service)

Inconvenient light switches encourage leaving on lights. It might pay to relocate light switches or to install two-, three-, or four-way switches. One 150-watt bulb left on overnight (12 hours) consumes 1.8 kWh per night, or 660 kWh per year. At $0.04 per kWh, you're losing $26.28 per year.

Removing light fixtures no longer needed will prevent their inadvertent use.

An in-line thermostat in a heat lamp used for freeze protection in the pump house will pay for itself through energy savings and convenience.

By matching the light intensity to the task, you can often decrease the amount of overall lighting needed (see the accompanying sidebar for determining light levels).

A different type of light source can give you as much or more light for a lesser energy cost. Indoors, fluorescent lights provide about four times more light per watt than incandescent bulbs, and last much longer. (normal fluorescent light ballasts are designed to operate between 50 degrees F and 105 degrees F. If fluorescent lights will be used in an unheated area, special ballasts should be used.) In the shop, high-pressure sodium lights are economical and give off an intense light. Portable spotlights on heavy stands that can be moved can reduce the need for intense overhead lighting. For outdoor lighting, a mercury vapor lamp provides more than twice as much light as incandescent light per watt. High pressure metal halide provides even more light, and high intensity discharge sodium lights provide five times as much light.

Although energy-efficient bulbs produce slightly less light, they consume 10-20 percent less electricity.

The substitution of one 100-watt incandescent bulb for two 60-watt bulbs generates a 16 percent electricity savings and provides about the same amount of light.

Adding switches to lighting circuits to permit single- or group-operation of lamps can tailor the lighting level to the task.

It saves energy to turn off incandescent lights for even seconds. Fluorescent lights should be turned off if they won't be used for 15 minutes or more.

DETERMINING LIGHT LEVELS

The following tables show the recommended levels of light for various tasks. The accompanying sidebar "Calculating Lighting Needs" shows you how to use these tables to figure the size and placement of lights to give you the proper foot-candles for your building and task. High-intensity discharge (HID) lamps include mercury, metal-halide, high-pressure sodium, and low-pressure sodium types. Remember, that as lamps age or become dirty, their light output will weaken.

Table 12. Recommended Illumination Levels

General Indoor Lighting Guide

Area or Activity[1]	Number of Recommended Foot-Candles	Typical Lamp Installation
Feed Storage:		
Haymow, silo, and grain bins	3	Incandescent in protected or dustproof fixtures
Feed inspection area and silo room	20	Incandescent floodlight
Concentrate storage and feed processing area	10	Incandescent floodlight
Livestock housing	7	Incandescent, fluorescent, or HID
Livestock examination area	20	Incandescent spotlight or floodlight or fluorescent
Stairways and ladders	20	Incandescent floodlight at top and bottom of stairs
Feeding areas	20	Incandescent, fluorescent, or HID
Machinery storage	5	Incandescent
Machinery repair area	30	Incandescent, fluorescent, or HID
Farm shop:		
General	30	Incandescent, fluorescent; HID if ceiling is over 12 feet
Bench and machine, sheet metal, and painting	50	Incandescent floodlight or fluorescent; adjust height and group fixtures as needed
Machine tool and detailed bench work	100	Incandescent floodlight or fluorescent; adjust height and group lamps as needed
Farm office	70	Incandescent or fluorescent
Rest rooms	30	Incandescent or fluorescent
Pump house	20	Incandescent or fluorescent

General Guide for Outdoor Lighting

Area or Activity	Recommended Foot-Candles	Types and Ratings of Lamps[1]
Security lighting	0.2	High-pressure sodium, 50 to 200 watts; and low-pressure sodium, 35 to 180 watts
General lighting for driveways, roads, and walkways	1.0	High-pressure sodium, 100, 200, 310, or 400 watts; low-pressure sodium, 180 watts; and metal halide, 250 to 400 watts for the best color
Activity areas, such as building entrances, livestock lots, docks, feeding areas, and recreation spots	3.0	High-pressure sodium, 200, 310, or 400 watts; metal halide, 250 to 400 watts for the best color; and low-pressure sodium, 180 watts

[1]Lamps listed here are not equal in light output (see table 13). Mounting height should be 20-25 feet, with the fixture shielded to have a 45° cutoff. Mercury lights are omitted here because of their lower efficiency for new installations.

Lighting Guide for Dairy Buildings and Equipment

Area or Activity	Recommended Foot-Candles	Typical Lamp Installation
Feeding area	20	Incandescent or fluorescent
Milking area	20	Incandescent or fluorescent
Cow's udder	50	Incandescent spotlight or fluorescent in milking parlors; fluorescent in stall barns
Milk-handling equipment:		
Milk room and general use	20	Incandescent or fluorescent
Washing area	100	Weatherproof fluorescent fixtures, two-lamp, 40-watt, adjustable height
Bulk tank, inside	100	Incandescent spotlights directed at tank interior, not over tank

Note: Adapted from recommendations of the Illuminating Engineering Society and American Society of Agricultural Engineers. (Reprinted from USDA, Farm Lighting)

CALCULATING LIGHTING NEEDS

The amount of light needed to illuminate an area depends on:

- Size of working area
- Height of working area (floor, workbench)
- Color of walls, ceilings and floors
- Height of lamp fixtures from floor
- Fixture spacing
- Reflector type

Based on fixtures with reflectors, mounted 7 to 10 feet above the floor, and medium reflectance from surroundings, you can figure that 2 lumens of output per lamp for each square foot of floor area provide an average light level of about 1 foot-candle per square foot at the working level. With different colored surroundings, or different reflectors, it can take more or fewer lumens to achieve 1 foot-candle. (Don't worry about lumens and foot-candles; we'll show you how to use them.)

Fixture spacing:

If you need between 5 and 10 foot-candles of light, the space between fixtures should be a maximum of 1 to 1 1/2 times the distance from floor to fixtures.

If you need over 10 foot-candles of light, the distance between fixtures should be the same (or less than) the distance from floor to fixtures.

In all cases, the distance from a fixture to a wall should be a maximum of 1/2 the distance between lamps.

Reflector types (illustrated in figure 32):

Use shallow dome for fixtures spaced 1 1/2 times the distance from floor.

Use standard-dome or deep-bowl for fixtures spaced the same as (or less than) the distance from floor.

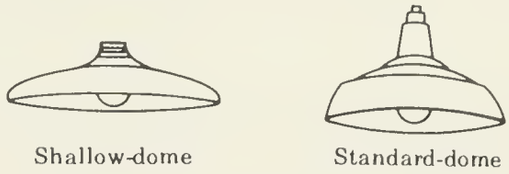


Figure 32. Reflector Shapes.

EXAMPLE:

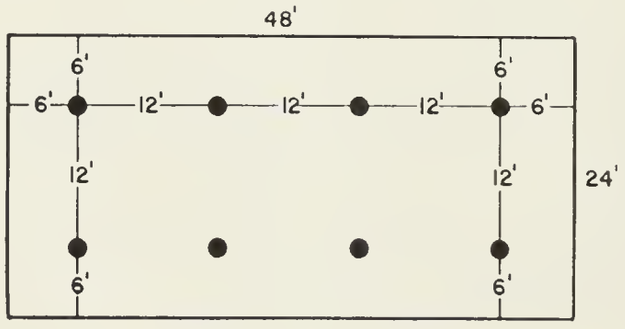
- A machinery storage area is 24 feet wide by 48 feet long.
- Light needed for the area (from table 12) is 5 foot-candles.
- Fixtures will be installed 10 feet above the floor.

Calculations:

1. Spacing between lamps = 10 to 15 feet.
2. Outside lamp-to-wall spacing = 5 to 7 1/2 feet.
3. Square footage of 24 x 48 = 1,152.
4. Fit lamps to room dimensions and spacing requirements (see figure 33):

   12 feet apart and 6 feet from walls = 8 lamps

Figure 33. Fixture Placement for Machine Storage Building.



5. Multiply the square footage times 2 lumens of output per lamp times the foot-candles needed:

   1,152 x 2 x 5 = 11,520 lumens

6. Find the lumens needed per fixture by dividing the total lumens by the number of fixtures:

$$\frac{11,520}{8} = 1,440$$

7. Refer to table 13 "Comparing Types of Light Sources." Choose the lamp size and type that provides the required lumens. When lumens fall between lamp ratings, use the next larger size or recalculate using other lamp spacings.

   From table 13, you'll see that you have a choice of 100-watt incandescent lamps (each produces 1,340 lumens), pairs of 15-watt 18-inch fluorescent lamps (1,500 lumens), or 18-watt low-pressure sodium lamps (1,800).

COMPARING TYPES OF LIGHT SOURCES

Light sources have differing efficiencies. Table 13 and figure 34 show how the number of lumens per energy used (watt) vary with the type of bulb. Incandescent bulbs are the most expensive in energy cost, emitting only 7 to 17 lumens per watt, and have a short life span. Low pressure sodium lights are the least expensive with an average output of 60 to 143 lumens per watt.

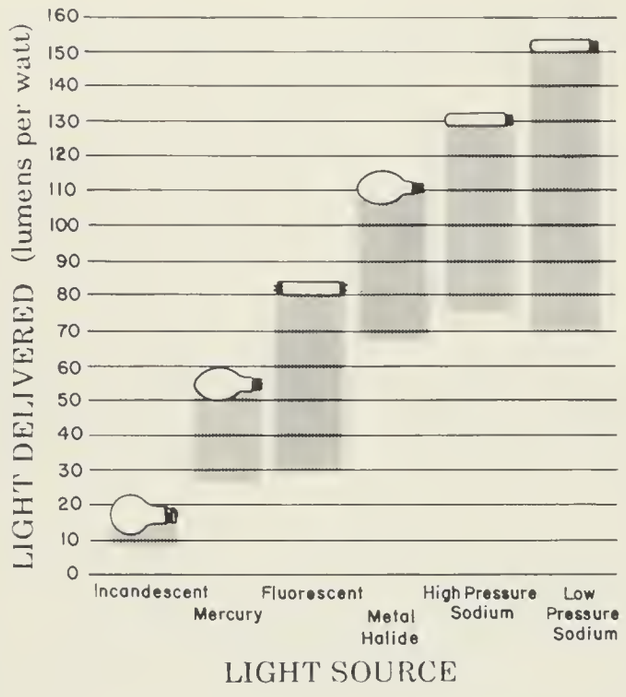


Figure 34. Comparing Energy Efficiency of Light Sources.

Electric Motors

Your farm's electric motors can add unnecessarily to the energy bill if not used wisely. Say you have four 3/4-horsepower motors operating ventilating fans during the summer. If each is drawing approximately 1.6 kW per hour and they are running 7 hours a day for a 120-day season, you can figure $215 annual power costs at $0.04 per kW. Or, maybe you have a 1/3-horsepower motor running a small fan or pump continuously year around. At 0.8 kW usage per hour, the annual power cost is $270 at $0.04 per kWh. A decrease in efficiency of even 10 percent would begin to add up on the power bill.

The keys to reducing energy use (and ultimately extending motor life) are protecting a motor from overheating and keeping it serviced and clean. Factors increasing internal motor temperature are:

- Demanding more horsepower from a motor than its nameplate rating.
- Voltages lower than 90 percent of the nameplate rating.
- High ambient air temperature.
- Altitude--each 330 feet increase in altitude above sea level raises internal motor temperature about 1 degree F.
- Direct radiation from the sun.
- Inadequate ventilation.
- Voltage delivered at the motor terminals below rated voltage.

A regular program for maintenance would include:

- Cleaning air intake holes at least every 10 hours of use.
- Lubricating bearings and gears according to time intervals specified in owners manual. (In hard-to-service locations, use motors with sealed-for-life bearings.)
- Cleaning the dust and dirt from motor windings every 3 months or sooner.
- Checking and cleaning starting switch contacts and motor fans periodically.
- Cleaning refrigeration-equipment motors and coils frequently.
- Checking motor pulley alignment and belt tension periodically.
- Checking motor shaft for "play."

To prevent overloading the electrical system and to maintain a low electrical demand, start motors in multi-motor systems one at a time.

A farm tool often overlooked is the air compressor. A 1/32-inch leak at 100 psig in your

Table 13. Efficiency of Various Light Sources

Lamp	Rated Size	Total Size[1]	Mean Lumens[2]	Lumens per Watt	Lifespan
	Watts	Watts	Number	Number	Hours
Incandescent					
Standard	15	15	110	7	2,500
	25	25	210	8	2,500
	40	40	410	10	1,500
	60	60	780	13	1,000
	100	100	1,580	16	750
	150	150	2,500	17	750
Extended Service					
	40	40	380	9	2,500
	60	60	700	12	2,500
	100	100	1,340	13	2,500
	150	150	2,100	14	2,500
Fluorescent, (cool white or warm white)					
Tubular, with a length in inches of:					
18	15	20	750	38	7,500
24	20	25	1,100	44	9,000
48 (energy saving[3])	34	39	2,700	69	20,000
48	40	46	2,800	60	20,000
96 (0.8 ampere)	110	126	8,000	63	12,000
96 (1.5 amperes)	215	245	12,000	49	12,000
Circular, with a diameter in inches of:					
6.5	20	32	600	19	12,000
8.3	22	34	760	22	12,000
12.0	32	45	1,450	32	12,000
16.0	40	54	2,060	38	12,000
High intensity discharge (HID)					
Mercury (HG)	50	65	1,300	20	16,000
	100	120	3,600	30	16,000+
	175	200	7,600	38	16,000+
	250	280	11,000	39	16,000+
	400	440	20,000	45	16,000+
Metal Halide (MH)	175	210	13,000	62	15,000
	250	290	18,500	64	15,000
	400	460	31,000	67	15,000
High Pressure Sodium (HPS)					
	50	70	3,600	51	16,000+
	70	90	5,220	58	16,000+
	100	125	8,550	68	16,000+
	150	180	14,400	80	16,000+
	200	240	19,800	82	16,000+
	250	295	27,000	91	16,000+
	310	365	33,300	91	16,000+
	400	470	45,000	96	16,000+
Low Pressure Sodium (LPS)					
	18	30	1,800	60	10,000
	35	55	4,800	87	18,000
	55	75	8,000	107	18,000
	90	120	13,500	112	18,000
	135	185	23,000	124	18,000
	180	230	33,000	143	18,000

[1]Including ballast, except for incandescents.
[2]Including ballast for fluorescents.
[3]Energy-saving fluorescents provide a special color of light; they are not intended for use below 60° F (16° C).
+ Lamp will operate much longer but with greatly reduced output.

Source: USDA, Farm Lighting.

system can cost you several hundred dollars a year. If your compressor turns on and off more than once an hour when you're not using it, check for leaks. Turn off the compressor when you won't be using it for several hours.

PURCHASING TIPS

For 10-horsepower or larger motors, select the new energy-efficient types.

Use 3-phase electricity when available; 3-phase motors are more efficient.

"Soft-start" motors have a lower starting current per horsepower than do standard types.

Oversized motors are energy-inefficient and use of oversized motors on your farm can waste hundreds of dollars a year in unnecessary energy costs. A 3-horsepower motor consumes about 3.9 kWh per hour of operation. A 5-horsepower motor working at the rate of a 3-horsepower motor consumes about 4.3 kWh.

Farm Shops

Use the sun to heat your shop. A passive solar wall collector built on the side of the building will help warm the shop during cold winter days.

When Building or Remodeling

When you're building or remodeling, use the natural features of a site to reduce your energy needs. Orient structures for maximum solar gain in winter, shading in summer, protection from wind and snow in colder months. Build into hillsides. Here are some things to keep in mind.

The less exterior wall surface, the less heat will escape. Ideal shapes are circular and square.

North windows should be kept to a minimum. South-facing windows allow full benefit from the sun. Carefully fitted double-glazed or triple-glazed windows cut heat loss on overcast days.

Plan entrances so they will be protected from winter winds. For frequently-used entrances in a home, airlock doors (double entry) minimize heat loss.

Locate open-front buildings, stockyards, and solar-heated facilities so they receive maximum benefit from the sun. The long dimension of a totally enclosed building constructed east-west exposes the maximum building area to the south and the sun's rays. Open-front buildings facing away from prevailing winter winds will usually benefit from cooling summer currents. Place tall buildings, such as tower silos, where they won't cast a shadow over feedlots.

Designing and locating new farm buildings for solar heating or drying can save substantially on your energy bill, especially if designed for multiple solar activities. Passive solar collectors could be used year around for a combination of crop drying, heating livestock or poultry enclosures, and heating water.

The location of buildings using solar is particularly important. Factors to consider include location of heat ducts so they don't cross driveways or impede livestock and length of heat ducts (even well-insulated ducts can lose heat).

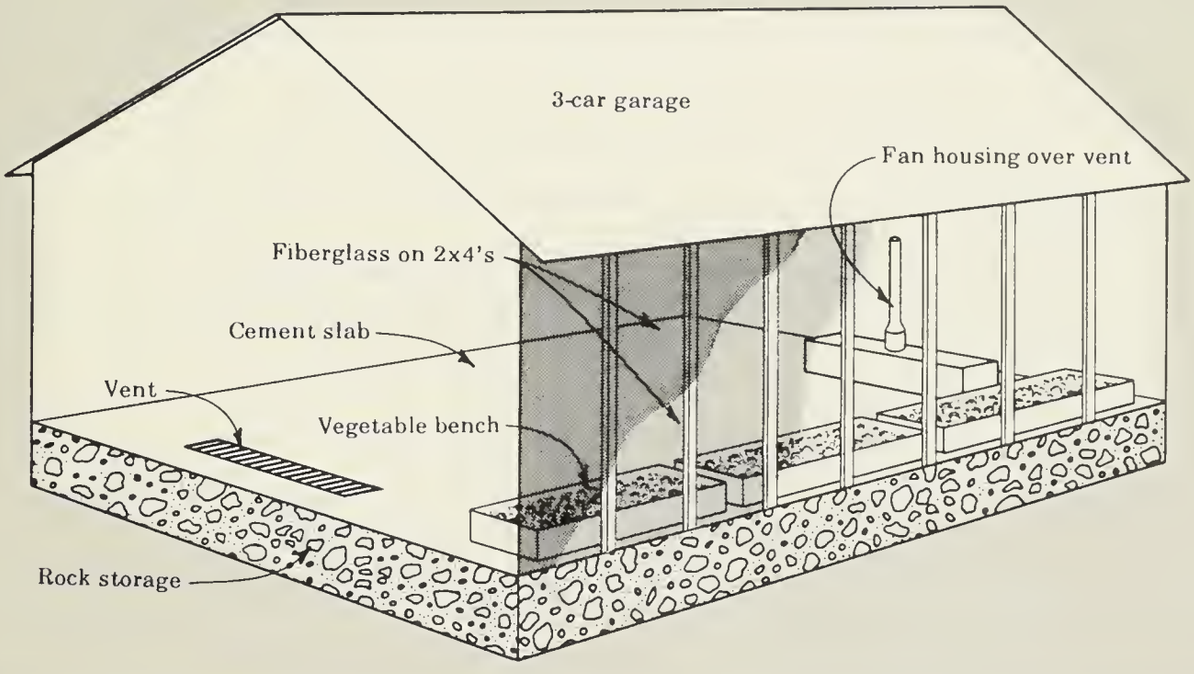
A well-constructed sunspace (sunroom, sun porch, solarium, or greenhouse) can funnel extra heat into a home as well as provide extra light and living space. Write to DNRC for the free publication on sunspaces.

A home-built vertical wall solar collector on a south wall can provide a portion of a home's heat on a sunny Montana winter day. The sun's rays heat air inside the collector; natural convection draws the warmed air directly into the living space. A collector also provides a buffer space on the outside of the wall, decreasing heat loss somewhat. The passive design requires no controls, blowers, or ducting. Because leaks are difficult to prevent, units of this type should be carefully built using a set of good plans.

In Rich Thieltges's shop in Chester, green peppers and tomatoes grow all winter in troughs along the south wall. Fresh vegetables are just one benefit of Rich's solar-heated shop with its average minimum temperature of 50 degrees F during subzero weather.

The cement slab of the large 3-car garage and shop lies over a 2-foot thick bin of rocks resting on plastic. On the south wall, corrugated fiberglass screwed to each side of the 2 x 4 stud wall acts as a huge double-pane window to allow the sun's heat into the building. Slots at each end of the slab let air circulate through the rocks. Atop one slot, an enclosed fan pulls warm air from the ceiling into the rocks, or reverses to draw air from the rock storage bin to heat the shop. On coldest days, the air drawn from the rocks is around 50 degrees.

Although his system keeps his shop warm enough without auxiliary heat, Thieltges says if he had it to do over he'd insulate below the rock storage area to prevent the heat from dissipating into the earth.



When Einar Hovland added a 50-foot by 50-foot addition to his farm shop near Great Falls, he installed a solar collector in the south wall for shop heat. Between a backing of 3/4-inch plywood, black Celotex™ and corrugated fiberglass, heated air flows around 2 x 4 baffles on the 16-foot high wall. When the air in the solar collector is 20 degrees warmer than the shop air, small fans turn on to draw the air into the room.

Ceiling fans force the warm air down to keep it circulating through the shop, and a filter at the cold air intake keeps the dust down. The solar collector operates efficiently to about 20 degrees below zero, warming both the addition and the rest of the shop. Louvers vent the collector to the outside during warm weather.

Hovland says it's a cheap way to heat a farm shop. The total 50-foot x 16-foot solar wall cost him around $1,100. He said he's saving between 60 percent and 70 percent on fuel. He's so pleased with it, he intends to do the same thing on his house.

APPENDIX

Behind the Scenes

In this appendix you'll first find technical publications that you may want to order for your files. Most publications from Montana Cooperative Extension Service and Montana Department of Natural Resources and Conservation (DNRC) are free to Montana residents. Although some extension bulletins are noted as out of print, copies may still be available from your local county extension agent, or through the public library. Publications from other sources may have a fee. Check with the producer for the cost.

Next are video tapes that you or a group may wish to order. Following that are the associations and magazines that provide a wealth of energy-saving ideas for farm and ranch.

Finally, but most important, are the individuals who contributed their time to this project.

It's impossible to include all energy-related publications for agriculture in this list. Those we have selected, though, often have resource lists of their own. So, like a chain reaction, once you acquire a few of these, you'll start to build your own resource list.

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Montana State University. Cooperative Extension Service. **Small Grains Integrated Pest Management.** Bulletin 4066. Bozeman, MT 59717.

Montana State University. Cooperative Extension Service. **Soil Sample Information Sheets.** Bulletin 2B1320. Bozeman, MT 59717.

Fuel Savings

Fuel Storage

Cornell University. Cooperative Extension Service. **Reducing Gasoline Storage Losses.** Bulletin FS-17. Ithaca, NY 14853. (1978)

Purdue University. Cooperative Extension Service. **Conservation, Storage & Handling of Fuel for Farm Machinery.** Bulletin AE-116. West Lafayette, IN 47907. (1985)

Farm Machinery

The Agricultural Engineering Department at the University of Nebraska has operated a tractor testing facility since 1920. All tractor models offered for sale in Nebraska must be tested at this facility. Test reports of individual tractors and annual summaries can be obtained by writing to:

Department of Agricultural Engineering, University of Nebraska, Lincoln, NE 68503

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